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THE MEASUREMENT OF NATURAL SELECTION

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I. The Status of Darwinism

BY organic evolution the broad-minded biologist of to-day understands merely the natural as opposed to the supernatural processes by which the hundreds of thousands of kinds of organisms which now inhabit or have inhabited the surface of the earth have come to possess the morphological and physiological peculiarities which distinguish them from each other. He believes that these differentiable types have been derived by a natural and relatively gradual process from earlier and, in the main, simpler forms.

This belief he shares with all his associates; the evidence in favor of it is considered by scientific men to be so strong that it has become scientific faith and scientific dogma. To-day, only the nature of the processes by which this evolution has proceeded interests biologists. Darwin's theory, and in large measure Darwin's evidence, have accomplished this. At one time Darwinism and organic evolution were synonyms, but now the suffixes "ian" and "ism" and the prefixes "neo" and "ultra" and "post" are combined with half a dozen different names and discussed with a glibness which is bewildering to some of those who are more interested in measuring the intensity of the factors which may have been active in organic evolution than in formulating theories concerning it.

Darwin's theory, viewed from such a distance that trivial details blend into large outlines, involves three propositions:

First, that variations from the typical condition of an existing species do occur.

Second, that these deviations may be inherited.

Third, that in the competition for existence which must result from

the inadequacy of space and food for all, certain individuals are by virtue of their characteristics better fitted to survive under their existing conditions of life than others.

For Darwin these were merely hypotheses to be conscientiously tested against all known facts. With the facts which Darwin painstakingly collected and sifted they seemed to agree so well that naturalists accepted his theory as the best explanation of the diversity of the organic world. Fifty years has furnished, it seems to me, a highly satisfactory substantiation of the first two propositions. We have forgotten that it was once necessary to convince biologists that variations do occur, and are now trying to measure the frequency and amount of variations, to determine what their proximate causes are, and to classify them. Variation and heredity are so intimately linked together that one can not be extensively investigated without considering the other. Since the pioneer work of Galton a few men have been actively engaged in the measurement of the intensity of heredity, and of recent years many more have been occupied with the experimental study of the physiological phases commonly known as genetics.

In consequence of this activity our knowledge of variation and inheritance is much more extensive than was that of Darwin—it would be to our shame if this were not true—but if biologists could all escape for a moment from the limitations of vision imposed by the tangle of post-Darwinian detail and by assumption and subsidiary qualification, and could look at the problems and the data of organic evolution as a whole and in the large I think they would be almost unanimous in regarding these two first propositions as so well established that they present no difficulty to the acceptance of the Darwinian theory.

The insecurity of the Darwinian tripod is to be seen in the weakness of the proposition that natural selection moulds the species by eliminating variations not adapted to the environment. While the first two hypotheses have been replaced by the masonry of quantitative science, the third remains largely a hypothesis, weakly reinforced by analogy and by the indirect evidence of adaptation.

To make more widely known the fact that natural selection is capable of quantitative treatment, of direct measurement, just as are variation and inheritance, is the purpose of this essay. It is not a brief for Darwinism, but a plea for direct quantitative researches into one of the more neglected problems of organic evolution.

II. The Problems of Selection

By the word selection in its most general evolutionary sense we mean merely that those individuals which leave offspring are not on the average representative of their generation, but that they differ in some regards from those which do not survive to be parents. In statistical terminology they are not a random sample of the population.

For the evolutionist a question of fundamental importance is this: Do the offspring of selected individuals differ from unselected individuals of the same population? This is, however, really a problem of variation and heredity and not of selection at all. Given variations which are heritable, stringent selection will change the type of the population. If after this change of type no more heritable variations occur, selection can effect no further change.

The history of cultivated varieties shows us that much can be accomplished by selection, but neither the history of animals and plants under domestication nor any amount of experimental evidence would be sufficient to demonstrate the correctness of the third Darwinian proposition.

This has often been recognized. "The real difficulty of Darwin's theory is the transition from artificial to natural selection," said Paul Janet. Darwin himself frankly tells us, "I soon perceived that selection was the keystone of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery to me."

Experimental breeding and statistical studies in variation and heredity can teach us much, but evolution, for the most part, has occurred outside the breeding pen. Some species have originated in the greenhouse and some in a hanging drop culture, but most species have come into existence and biological dynasties risen to dominance and sunk into decadence in the fields and swamps and mountains where organisms live in competition and cooperation, as host and parasite, as destroyer and destroyed. From the standpoint of evolution the vital question concerning selection is: Does selection (natural, sexual or genetic) occur in nature?

Is a selective death rate such an important factor that equipped with proper instruments the biologist can go out into free nature and measure its intensity? If he can, then the Darwinian theory of evolution must detain us longer; if he can not, we must lay Darwinism on one side, and maintain towards it, as towards all other theories for which critical evidence is wanting, an attitude of agnosticism.

III. The Measurement of Selective Elimination

The hypothesis of the existence of the evolutionary factor known as natural selection is dependent upon the assumption that individuals vary in their capacity to withstand the pressure of their environment, and that the differences in resistance to untoward external conditions are associated with and due to differences in the physical, physiological or psychical characteristics of the organism.

It does not assume that every death is selective. Many are due to factors which eliminate irrespective of any particular character; many survivals are due to a fortuitous combination of favorable environmental

conditions. Concerning the fate of any individual we can say nothing. The problem is, therefore, a statistical one; evolution, as it occurs in nature, is not a problem of "individuals" but of "populations."

A. *The Protective Value of Color*

For a century field naturalists have observed the close similarity between the colors of organisms and their environment, and have seen in this resemblance an adaptation for protection. Since the advent of the selection theory protective and aggressive resemblance, warning colors, recognition characters and mimicry have been prominent in biological literature, and are conceptions associated with some of the most honored names in biology. Yet almost all the evidence has been comparative, and attempts to determine empirically whether given color patterns are in the long run of vital significance are discouragingly few, and some biologists are now questioning whether the so-called protective adaptations have any value at all.

One of the simplest and most direct tests of the value of any character in determining the chances of survival of an individual is that of Di Cesnola for the protective value of color in *Mantis religiosa.*[1] In Italy the green individuals of this species are found on green grass, the brown ones upon grass burnt by the sun. If the color has any protective value there should be a higher death rate from enemies when the insects are exposed on vegetation of a color unlike their own.

Altogether 110 insects, 45 green and 65 brown were secured and were exposed on separate plants as follows:

Green insects on green plants	20
Green insects on brown plants	25
Brown insects on brown plants	20
Brown insects on green plants	45

The experiment began August 15 and observations were made daily for seventeen days. Of the forty individuals exposed on vegetation of similar color, every one survived throughout the entire experiment. All the green individuals exposed on brown grass were killed in eleven days; of the forty-five brown individuals exposed on green grass, ten survived to September 1, when a severe gale destroyed the experiment. This is all made clear by Fig. 1.

The biometrician would like to see this experiment carried out on a much larger scale, but when we consider that not one of the forty insects exposed on similarly colored vegetation was killed at the end of seventeen days, while sixty of the seventy exposed on dissimilarly colored vegetation were eliminated[2] by the end of the first eleven days, I

[1] Di Cesnola, A. P., "Preliminary Note on the Protective Colour in *Mantis religiosa*," *Biometrika*, Vol. III., pp. 58–59, 1909.

[2] Most of the insects were destroyed by birds; five were known to have been killed by ants.

think we must regard Di Cesnola's evidence as rather strongly indicating a real protective value in the color dimorphism.

For vertebrates two papers are available. Davenport[3] and Pearl[4] have made observations on the relative number of self-colored and of barred or pencilled birds killed by enemies. Davenport finds that out of 24 chicks from five to eight weeks old killed on one afternoon by three crows only a single one was other than self-colored, although twenty per cent. of the flock of about 300 chicks "had a pencilled or

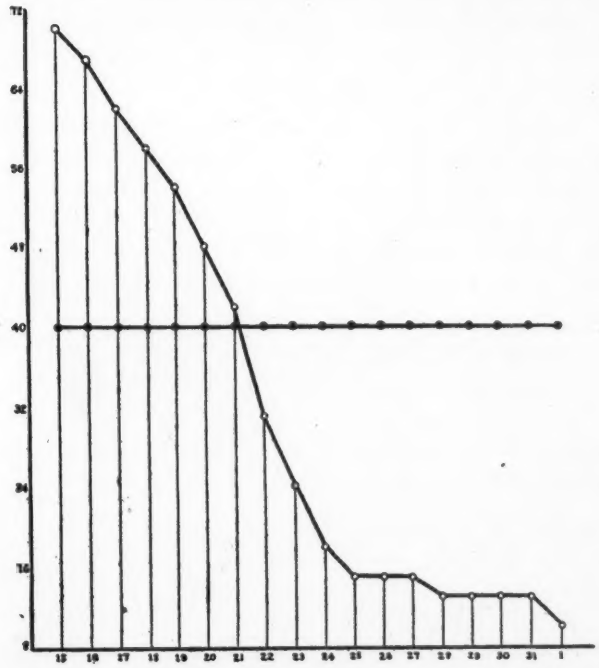

FIG. 1. NUMBER OF INSECTS SURVIVING DAY BY DAY IN SERIES OF BROWN AND GREEN *Mantis* EXPOSED ON BROWN AND GREEN VEGETATION. Ordinates = dates; abscissæ = number of individuals. Similar color in insect and environment represented by heavy dots; dissimilar combinations by circles.

striped marking more or less like that of the female jungle fowl or ordinary game." He concludes, "this fragment, then, so far as it goes, indicates that the self-colors of poultry which have arisen under domestication, tend to be eliminated by the natural enemies of these birds, and the pencilled birds are relatively immune from attacks because relatively inconspicuous."

Photographs by Pearl show that the barred birds are much less conspicuous in their surroundings than are self-colored ones. Theoretically,

[3] Davenport, C. B., "Elimination of Self-coloured Birds," *Nature*, Vol. LXXVIII., p. 101, 1908.

[4] Pearl, R., "Data on the Relative Conspicuousness of Barred and Self-colored Fowls," *Amer. Nat.*, Vol. XLV., pp. 107–117, figs. 1–4, 1911.

their mortality from predaceous enemies ought to be lower, but from a rather large series of observations in his experimental poultry plant only negative results are secured. The actual figures are:

Class of Birds	Number in Original Flock	Eliminated by Known Enemies, Almost all Rats	Eliminated by Unknown Enemies, Chiefly Predaceous Birds	All Eliminated Birds
Self-colored	336	6 = 1.79%	29 = 8.63%	35 = 10.42%
Barred	3007	68 = 2.26%	222 = 7.38%	290 = 9.64%
Totals	3343	74	251	325

It will be noticed that when the chicks eliminated chiefly by predaceous birds are examined alone, the proportion of self-colored birds is a little higher, but without further statistics no significance could be attached to the difference.[5]

B. *Structural Characters in Relation to Survival*

The comparisons in the preceding section were drawn between well-marked color varieties. Many more experiments of this kind are desirable, but if natural selection be a factor of the potency required to account for the origin of specific characters by the accumulation of small variations, it must be shown that the peculiarities of form or color which separate one individual from another are of significance in determining the ability to more than hold its own in competition with its fellows. So far as I am aware pertinent data are available for structural characters only.

Experiments with Crabs

The pioneer in the measurement of the intensity of natural selection was W. F. R. Weldon. His first attempt to determine whether survival may depend upon definite physical characters was made with the common shore crab, *Carcinus mœnas*.[6]

[5] It would be very interesting if data could be obtained from flocks of young chickens in a diversified environment—*i. e.*, one in which there is a variety of underbrush, weeds, stones, etc., giving wider opportunity for hiding. Davenport's chicks were on a "well-cropped pasture" and Pearl's birds "ran together on the same open, turf-covered range." Now it is quite possible that barring might afford no protection on open turf, and yet be most advantageous in a thicket. Some poultry man could do a very good service to science by appropriating a few hundreds of young birds to the hawks and crows, allowing them to have the run of a lot affording a diversity of shelter. Only where the habitat simulates closely the kind in which animals are found in nature can an experiment of this kind be really critical.

[6] Weldon, W. F. R., "An Attempt to Measure the Death-rate due to the Selective Destruction of *Carcinus mœnas* with Respect to a Particular Character" (Report of the Committee for Conducting Statistical Inquiries into the

Fig. 2 will be recognized at once, even by the reader whose knowledge of marine biology is limited to the menu-fauna of the city restaurant as the outline of the solid upper portion of the crab's body known as the carapace. In measuring the frontal breadth[7] of *Carcinus* from a particular spot of beach near the Marine Biological Laboratory at Plymouth, Weldon and Thompson noticed a peculiar change from year to year. For crabs of the same length of carapace,[8] the frontal breadth seemed to be decreasing.

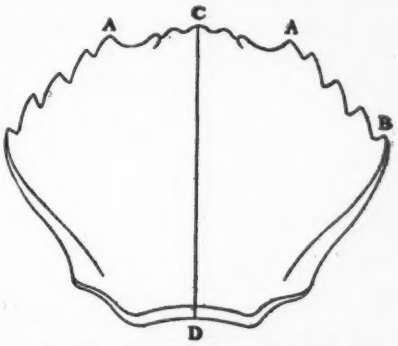

FIG. 2. OUTLINE OF THE UPPER SURFACE OF THE CARAPACE OF THE SHORE CRAB, *Carcinus mœnas*.

I have tried to make this clear by a diagram. In Fig. 3 the individuals are classified into twenty-five groups according to length of carapace and the proportional frontal breadth[9] for each class represented for the three years by the position of the circles.[10] The general slope of the connecting lines convinces one that the Plymouth Sound crabs, as observed by Thompson and Weldon, were undergoing a pronounced change in frontal breadth.

The two reasonable hypotheses to account for this decrease are: (1) A modification of the young individuals by the direct action of a changing environment, (2) a decrease in the average frontal breadth in the population due to elimination of the individuals with broader frontal dimensions.

A change in the environmental conditions of Plymouth Sound was undoubtedly in progress during the time when Professor Weldon's observations were made. The streams bring into the sound large quantities

Measurable Characteristics of Plants and Animals), *Proc. Roy. Soc. Lond.*, Vol. XLVII., pp. 360–379, 1894. Also, W. F. R. Weldon, presidential address to the Section of Zoology, British Association, Report of Bristol Meeting (1898), pp. 887–902, 1899. Interesting and valuable supplementary information concerning Weldon's studies on selective elimination are to be found in Pearson's biographical memoir of Professor Weldon (see *Biometrika*, Vol. V., pp. 1–52, pl. I.–V., 1906).

[7] The distance between the tips of the extra-orbital teeth, from the point *A* to the point *A'* in the figure.

[8] There is no way of knowing precisely how old an individual beast is; if the specimens for different series are sorted into classes of about the same length of carapace, on a line from *C* to *D*, and if there is no reason to suspect any differences due to special environmental influences, dimensions of other parts of the shell can be compared in different lots with reasonable confidence that animals of about the same average age are being examined.

[9] The frontal breadth is expressed in thousandths of the carapace length.

[10] For 1898 the number of observations is not large enough for thoroughly satisfactory determinations.

of fine china clay, while the growing cities along the shore and the shipping have greatly increased the refuse thrown into the harbor. The construction of a huge artificial breakwater has minimized the scour of the tide and the waves of severe storms which formerly swept the fine silt out of the sound, so that this was constantly increasing in amount during the period. These physical changes affected the fauna and some organisms disappeared and were only to be found outside the breakwater.

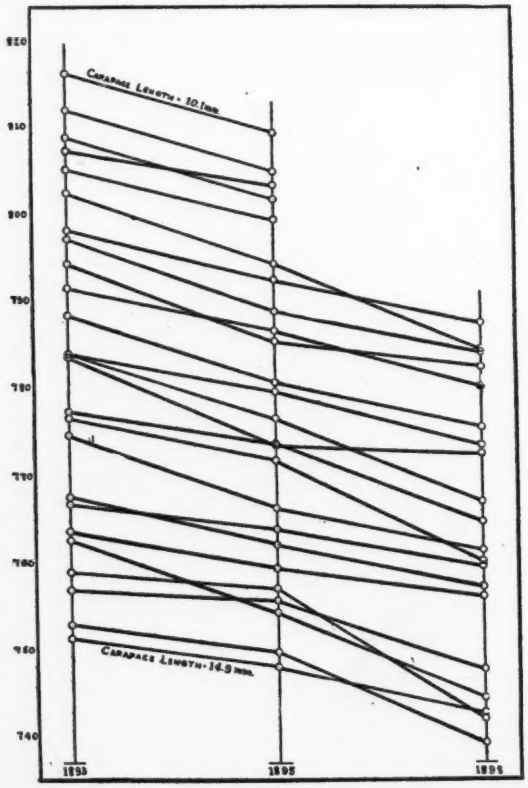

FIG. 3. CHANGE IN FRONTAL BREADTH OF *Carcinus*. The slope of the lines shows the change in mean relative frontal breadth for crabs of different length of carapace.

As a first series of experiments Weldon put crabs in a large vessel of sea water in which a quantity of fine china clay was kept from settling by a slow automatic agitator. After a period of time both dead and living individuals were measured. In every case the crabs which died were on the whole distinctly broader than those which lived through the experiment, so that a crab's chance for survival could be measured by its frontal breadth. When the experiment was performed with clay coarser than that brought down by the rivers the death rate was smaller, and was not selective.

By washing the stones under which the crabs live along the beach Professor Weldon obtained a silt of a finer texture than the china clay he had been able to use. This was employed in experiments of the same kind, with identical results.

There seems no reason to suppose that the relation of the crabs to the mud on the beach is different from that in the aquarium. Whenever the fine sediment is stirred up a selective elimination of crabs must occur. It is this selective elimination which Weldon regarded as furnishing the explanation of the decrease in frontal breadth observed in the measurements in 1903, 1905 and 1908.

Not content with these experiments, Weldon tried to obtain evidence of an entirely different kind. He arranged several hundred aquaria in each of which a young crab from the beach was kept in clear running sea water—and so entirely free from the influence of the mud. They were allowed to moult and grow and harden new shells. When measured they were found to be unmistakably broader than wild crabs of the same length. This is precisely the result to be expected if a selective elimination of broad-fronted individuals occurs in nature.

The source of this difference in capacity for survival seems to lie in the way in which the crabs filter the water entering their gill chambers. Professor Weldon found that a narrow frontal breadth renders one part of the process of filtration of water more efficient than it is in crabs of greater frontal breadth. The gills of the crabs which died during the experiments were covered with fine white mud, and this was not found in the gills of the survivors.

The labor of these experiments—the daily care of hundreds of animals, the thousands of measurements and the drudgery of calculation—was excessive. Most discouraging of all, perhaps, were the sterile and hostile criticisms which are so often the portion of a pioneer.

Observations on Other Invertebrates.

Results which may be logically attributed to the action of natural selection but which by reason of the possibility of other explanations are not conclusive evidence for its potency, have sometimes been secured by biometricians concerned with other problems. For instance, Warren[11] adduces "the elimination of the physically unfit" as one of the factors to account for the difference in variability of the termites of the same nest at different seasons. Possibly this factor may also account in part for differences in variability from nest to nest, but of course much more extensive and direct evidence must precede any final conclusions.

Another study of variation in insects, social and otherwise, is that

[11] Warren, E., "Some Statistical Observations on Termites, Mainly Based on the Work of the Late Mr. G. D. Haviland," *Biometrika*, Vol. VI., pp. 329–347, 1909.

of Kellogg and Bell.[12] They decide against natural selection, but their evidence for the lady beetle, *Hippodamia convergens,* can not be regarded as conclusive since they have made no direct comparison of eliminated and surviving individuals. Their case for the honey bee where observations are made upon free flying individuals and those which have not yet left the shelter of the hive, is much better, but even here I must feel that their numbers are too small to give finally conclusive results in a problem so difficult as that of natural selection. Furthermore, they suggest that the more abnormal individuals may be made way with before they have the opportunity of leaving the hive.

A most suggestive result was obtained by Schuster in an investigation of deep and shallow water crabs of the genus *Eupagurus.*[13] He finds that for both sexes, but especially for the males,[14] the individuals from deep water were more variable than those from shallow water.[15] Schuster wisely leaves the determination of the reason for this difference in variability to the time when more data, and data collected under the guidance of this first study, shall be available. He points out, however, that if these differences in variability are not those of deep water and shallow water local races, but arise anew in each generation, they must be due either to the direct influence of the environment or to selection. If elimination be the true explanation the less variable shallow-water forms would be regarded as a selection from the more variable deep-water population.

Turning again to studies carried out primarily to test the possible action of natural selection, we may mention the work of Browne on the medusa, *Aurelia aurita.*[16] In this jelly fish the number of marginal sense organs, tentaculocysts, is definitely fixed in the larval stage commonly known as the Ephyra, and by a comparison of collections of Ephyræ and adults it is possible to determine whether variation in the number of the marginal sense organs affects the chance of survival from larval to adult life. Since all of the young and adult populations compared were sensibly identical, one must conclude that neither an increase nor a decrease in the number of tentaculocysts is so injurious that there is any selective elimination during development.

Crampton's study of pupal and pupal-imaginal elimination in the

[12] Kellogg, V. L., and Ruby G. Bell, "Studies of Variation in Insects," *Proc. Wash. Acad. Sci.,* Vol. VI., pp. 203–332, 81 figures, 1904.

[13] Schuster, E. H. J., "Variation in *Eupagurus prideauxi,*" *Biometrika,* Vol. II., pp. 191–210, 1903.

[14] Deep water forms were those taken at a depth more than 35 meters; shallow water forms from a depth of less than 35 meters.

[15] The males are more variable than the females, in both deep and shallow water.

[16] Browne, E. T., "Variation in *Aurelia aurita,*" *Biometrika,* Vol. I., pp. 90–108, 1901.

Ailanthus silk-worm moth[17] I will pass by without discussion, since I believe he is soon to publish further observations on the same subject.

Weldon's work on natural selection was not limited to crustacea, but extended to the mollusca as well.

The shells of certain snails, such as *Clausilia* and *Helix,* is essentially a tube increasing in size as the animal grows older and wound in a spiral, or more properly a helix, around a central axis with the successive coils in contact. If one of these shells be cut longitudinally, the central cone, or columella, as it is technically called, will be laid open and will appear as a narrow conical tube extending the whole length of the shell, while the tube which contained the animal will be cut across twice in each complete revolution and will appear in cross section.

This point is made quite clear by an examination of the three diagrams (Fig. 4).

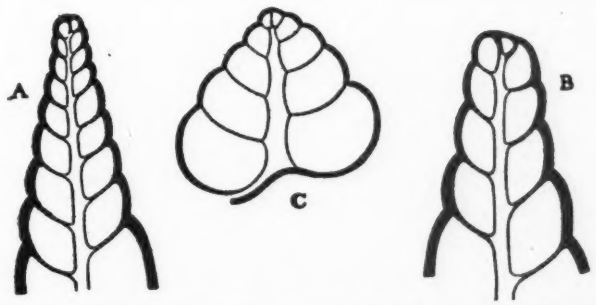

FIG. 4. LONGITUDINAL SECTIONS OF *Clausilia laminata* (*A*), *Clausilia italia* (*B*), and *Helix arbustorum* (*C*), after Weldon and Di Cesnola in *Biometrika.*

By deft manipulation such sections can be prepared. A shell may be ground upon a soft stone until a plane which extends almost exactly through the central columella is exposed.[18] From such a preparation it is quite possible to make the measurements which determine the pitch and several other characteristics of the spiral.

The shell of these snails is a permanent structure. In the adult the whorls first laid down by the young animals can be measured. Now it is clear that one can compare the properties of the portions of the spiral already laid down in the shell of a young snail with the same portions in the shell of an adult. In snails, as in other animals, not all individuals survive to adult life. The problem is to find out whether the properties of the first-formed portions of the spirals of the shells of

[17] Crampton, H. E., "Experimental and Statistical Studies upon Lepidoptera. I. Variation and Elimination in *Phylosamia cynthia,*" *Biometrika,* Vol. III., pp. 113–130, 1904.

[18] To be sure, the work is exceedingly tedious and many shells are accidentally spoiled, but four or five may be prepared in a day's work and in the course of time a number sufficient for statistical work may be secured.

individuals which have survived to adult life differ from those portions of the shells of young snails, part of which will survive and part be eliminated. If differences do occur they are most easily explained as due to a selective mortality in the animals during their period of growth.

Details of measurement and calculation are entirely too elaborate and complicated for explanation here. In two studies, one by Weldon[19] on *Clausilia laminata* from Gremsmühlen in Holstein and one by Di Cesnola[20] on *Helix arbustorum* from the banks of the Isis near Oxford, the authors found that while there is no difference between the mean characters of young and old shells there is a distinct difference in variability. This kind of selective elimination which recurs every generation and by which the existing type is maintained (without necessarily giving rise to any progressive change) Weldon designates as periodic, in accordance with Pearson's terminology.[21]

The reader must not conclude from what has just been said that Weldon regarded variation in the peripheral radii as the direct cause of the selective elimination. "Such selection is, of course, 'indirect,' that is to say, the life or death of the individual is determined in each case by the value of a (probably large) number of correlated characters, of which the length of the peripheral radius is only one." With justice Weldon emphasizes the minuteness of the structural differences which seem to mark the boundary between fitness and unfitness for survival in *Clausilia laminata.*

The results of Weldon's investigation[22] of *Clausilia italia* did not agree with that of his former study of *C. laminata.* By some readers this fact will be interpreted as vitiating entirely any conclusion to be drawn from all this laborious work on shells. To my mind this attitude is quite wrong. Laying aside the fact that Weldon has suggested biological reasons which may explain why no change in variability was observed between young and old individuals in *C. italia,* we must bear in mind the fact that there is no justification whatever for assuming that natural selection, either secular or periodic, is to be observed at all times in all species. Naturally contradictory results call for repetition and amplification and for more refined control of conditions—but these are the things which make for the advancement of science. Only the merest beginning has been made in the study of selective elimination, but Weldon has shown us the way in which the problem may be attacked in two large groups of invertebrates. If other workers with his patience are ready to volunteer their service to this phase of evolution,

[19] Weldon, W. F. R., "A First Study of Natural Selection in *Clausilia laminata,*" *Biometrika,* Vol. I., pp. 109–124, 1901.

[20] Di Cesnola, A. P., "A First Study of Natural Selection in *Helix arbustorum,*" *Biometrika,* Vol. V., pp. 387–399, 1907.

[21] Pearson, K., "Grammar of Science," 2d ed., pp. 412–414, 1900.

[22] Weldon, W. F. R., "Note on a Race of *Clausilia Italia,*" *Biometrika,* Vol. III., pp. 299–307, 1904.

the next ten years ought to see a material advance in our knowledge of the least investigated of the Darwinian principles.

Studies of Vertebrates.

The relative ease with which large numbers of individuals can be secured and observed is an ample explanation of the fact that practically all the studies of selective elimination have been made on invertebrates.

To Dr. H. C. Bumpus belongs the credit of the first effort to determine whether the death rate among vertebrates may depend in some degree upon the measurable physical characteristics of the individual. Indeed, in the attempt to apply quantitative methods to the problem of natural selection Bumpus[23] was a close competitor for priority with Professor Weldon. His statement of the problem, like that of Professor Weldon, is beautifully clear:

> A possible instance of the operation of natural selection, through the process of elimination of the unfit, was brought to our notice on February 1 of the present year (1898), when, after an uncommonly severe storm of snow, rain and sleet, a number of English sparrows were brought to the anatomical laboratory of Brown University. Seventy-two of these birds revived; sixty-four perished; and it is the purpose of this lecture to show that the birds which perished, perished not through accident, but because they were physically disqualified, and that the birds which survived, survived because they possessed certain physical characters. These characters enabled them to withstand the intensity of this particular phase of selective elimination, and distinguish them from their more unfortunate companions.

From his measurements of various bodily dimensions Professor Bumpus concluded that the birds which perished were actually differentiated from those which survived. Some of the differences, however, are so small that to the cautious statistician this attempt to measure the influence of a selective death rate on the type of a population of birds living in a state of nature seems suggestive rather than finally conclusive.

This must not be read as a criticism of Bumpus's work, for he not only saw the problem and the possibility of applying the new methods to it, but he also gave us the full results from an unusual opportunity.

First and last, considerable has been written concerning natural selection in man. Most of the arguments are purely general or specu-

[23] Bumpus, H. C., "The Elimination of the Unfit as Illustrated by the Introduced Sparrow, *Passer domesticus*," Biological Lectures from the Marine Biological Laboratory, Woods Hole, 1908, pp. 209–226, Boston, 1899. For further statistical constants calculated from Bumpus's data see a note entitled, "A Neglected Paper on Natural Selection in the English Sparrow," *Amer. Nat.*, May, 1911, p. 314–318.

lative, but Beeton and Pearson[24] have succeeded in obtaining more definite evidence.

From extensive researches on inheritance in man, Pearson and his associates have shown that duration of life gives much lower correlations—both parental and fraternal—than the substantial values found for other physical and psychical characters. If the duration of life of an individual were absolutely determined by physical and mental fitness, then one would expect it to show a correlation as high as that found for other characters. The fact that the values are regularly and conspicuously lower evidences for the existence of a non-selective death rate. The relative amount of the selective and non-selective death rate may be roughly estimated from the reduction in correlation as one passes from the inheritance of characters in general to that of longevity. By this means Beeton and Pearson calculated that from fifty to eighty per cent. of the death rate in civilized man is selective.

C. *The Fitness of Organs*

Except among the lowest forms of life, every animal or plant is made up of a large number of parts which are differentiated in form and function. The fitness of such a complex organism for self preservation and perpetuation probably depends not merely upon the degree of development of its several component members, but also upon the nicety with which they are coordinated.

Undoubtedly the proper way of taking up the study of Natural Selection is to compare by means of the measurement of particular organs series of individuals which survive with series which perish, but after this is done in a large number of cases we shall have considered only the first part of our problem.

This first phase consists in finding out whether variations in the form, size or other property of an organ affects its efficiency to such an extent as to prejudice the chances of survival of the individual possessing it.[25]

Involving, as it does, questions of structural characteristics and functional efficiency this is at bottom a problem on the boundary line between morphology and physiology. For several years it has seemed to me that we might, in the long run, make better progress in the study of the problems of evolution if we turned our backs on some of its more

[24] Beeton, Mary, and K. Pearson, "A First Study of the Inheritance of Longevity and the Selective Death-rate in Man," *Proc. Roy. Soc. Lond.*, Vol. LXV., pp. 290–305, 1889. Beeton, Mary, and K. Pearson, "On the Inheritance of the Duration of Life, and on the Intensity of Natural Selection in Man," *Biometrika*, Vol. I., pp. 50–89, 1901.

[25] In actual work one is at once confronted by the difficulty that variations in the organ he is studying may have no real influence upon the chances of survival but merely an apparent significance due to its correlation with other organs.

complex phases and devoted ourselves temporarily to the morphological and physiological problems upon which they rest.

While testing out this idea in studies of the relationship between structural characteristics and fertility in various fruits, certain inconsistencies in results were found which could be most easily explained by the assumption that there is a selective elimination in which ovaries

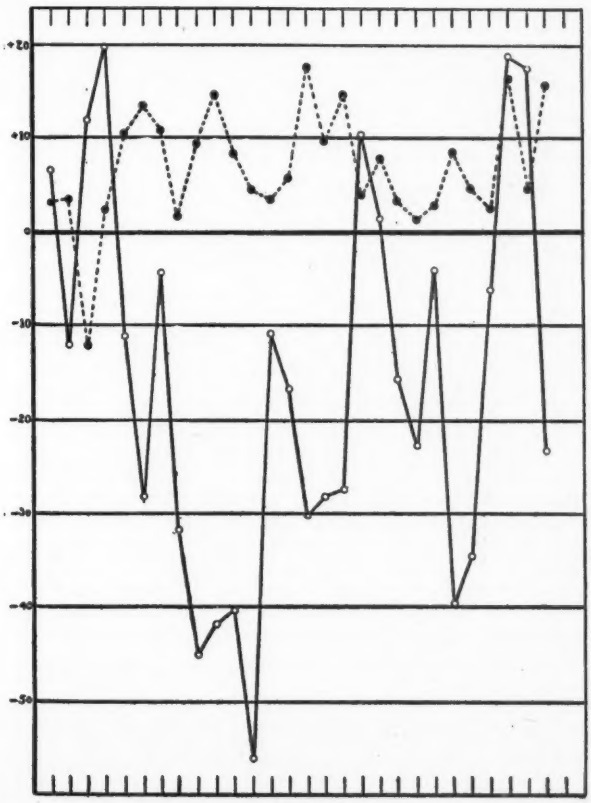

FIG. 5. COMPARISON OF MATURED FRUITS WITH FALLEN OVARIES FOR TWENTY-EIGHT INDIVIDUAL SHRUBS OF *Staphylea*. Differences expressed in percentages of the mean of the eliminated series. Solid dots and broken lines = mean number of ovules; circles and firm lines = radial asymmetry.

of certain types are extensively weeded out. Direct investigation proved the correctness of this assumption. The results will be set forth very briefly.[26]

In the selective elimination which occurs during the development of the ovary of the American bladder nut, *Staphylea*, into a fruit, the

[26] Those who care for a detailed account may find it in three papers: (*a*) "Is there a Selective Elimination in the Fruiting of the Leguminosæ?" *Amer. Nat.*, Vol. XLIII., pp. 556–559, 1909; (*b*) "On the Selective Elimination during the Development of the Fruits of *Staphylea*," *Biometrika*, Vol. VII., pp. 452–504, 1910; (*c*) "On the Selective Elimination of Organs," *Science*, n. s., Vol. XXXII., pp. 519–528, 1910.

mean number of ovules is materially increased. For a small series of developing ovaries taken at the Missouri Botanical Garden in 1906, the oldest—the group from which the most elimination had taken place—had about eight per cent. more ovules per fruit than the youngest. In large samples taken in 1908, the fruits which matured had about seven per cent. more ovules than those which were eliminated. The same result is seen if the material is split up into twenty-eight individual pairs of samples, each from a separate tree. This is made clear by Fig. 5. The solid dots connected by broken lines show the percentage excess of the matured fruits over the fallen ovaries in the number of ovules. In twenty-seven cases out of twenty-eight the number is larger in the ovaries which mature!

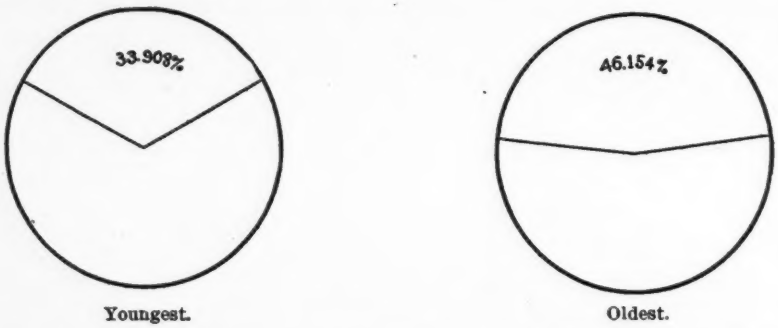

FIG. 6. PERCENTAGE OF OVARIES WHICH ARE PERFECTLY RADIALLY SYMMETRICAL IN YOUNGEST AND OLDEST COLLECTIONS, Missouri Botanical Garden, 1906.

The ovary of *Staphylea* is three-celled. If each cell contains the same number of ovules, *e. g.*, 8–8–8, it may be regarded as radially symmetrical, while if the numbers differ from locule to locule, for instance 8–7–8 or 9–10–8, the ovary may be described as radially asymmetrical. If this radial asymmetry be expressed by a statistical constant such that a perfectly symmetrical fruit shall have a degree of asymmetry of 0, while the coefficient increases as the ovaries become more irregular, one can compare asymmetries in the ovaries which do and those which do not develop to maturity as easily as he can the means.

Fig. 6 shows the percentage of perfectly symmetrical ovaries in the youngest and oldest series of the 1906 collection. The conclusion that the conspicuously higher percentage of perfectly symmetrical ovaries in the oldest collection is due to a selective mortality by which the more irregular ones are weeded out is fully substantiated by the statistics of 1908.

The average asymmetry for the matured fruits for 1908 is about seventeen per cent. lower than the mean for the eliminated sample. For the individual trees the results are somewhat more irregular than they were for the mean number of ovules, but Fig. 5 shows that in

twenty-one cases to seven the asymmetry of matured fruits is less than that of the ovaries which do not complete their development. Taken as a whole, the differences show an unmistakable tendency to fall far to the negative side of the 0 bar.

Not merely the degree of radial asymmetry of the ovary, but the number of its locules which have an odd number of ovules, seems to be of consequence in determining whether an ovary shall complete its development. Ovaries with even numbers—6, 8, 10, 12—of ovules in their locules have a better chance of developing to maturity than do those with one or more locules with an odd number. The question is too involved for adequate discussion, and I will leave the subject with a mere reference to Fig. 7 which shows that in the 1908 series the reduction in the percentage of "odd" locules is a very material one.

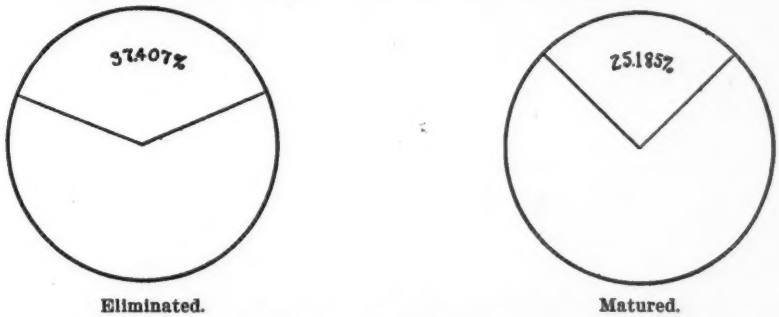

FIG. 7. PERCENTAGE OF "ODD" LOCULES IN ELIMINATED AND MATURED OVARIES OF *Staphylea*—1908 collection.

The work just outlined has been rather drastically criticized on the ground that studies on the selective elimination of organs can never have any bearing on the problem of evolution. I think there is room for differences of opinion on this point, but at present the purely morphogenetic and physiological sides of the problem are of paramount interest; our knowledge of facts is too meager to justify speculations on so complex a problem as that of the origin of species.

IV. CONCLUDING REMARKS

In the paragraphs which have preceded these I have tried to set forth honestly the results which have been secured in attempts to ascertain by direct quantitative methods the intensity of the selective elimination which may occur in nature.

What is the general significance of these results? What claim have they to the special attention of scientific men?

First, let us premise that *the measurement of natural selection* is not synonymous with such an expression as *the demonstration of the natural selection theory.* Upon the application of biometric methods many supposedly valid biological theories have shrunken to nothing;

possibly this may ultimately be the fate of the natural-selection theory. In approaching the problem our aim is not to "get positive results," but to find out the truth. Our object is not to bolster up a venerable and out-of-fashion hypothesis, but to test conscientiously that hypothesis against concrete data.

Like other theories, the Darwinian theory must stand or fall according as the evidence of quantitative biology shall be for or against it. If the micrometer scale and the calculating machine show that any given character has no influence in determining whether an individual shall survive, then for that organ, in that species at the time under consideration, evidence for the potency of selection is wanting.

The problem is a difficult one; *a priori* one would expect most generally to find no changes taking place in the characters of a species because of a selective death rate. If natural selection be actually at work in nature, it is likely that the ancestors of individuals collected in the open will have been subjected to the selective factors which one is trying to measure, and that the race will be held pretty close to the attainable limit of perfection. It is more likely that a selective elimination which recurs every generation will be observed than one of the kind that brings about changes in specific characters. Only in rare cases when a new territory is opened to organisms or some special modification of environment (inorganic or organic) has taken place can we reasonably expect to see the changing of types going forward. Possibly the very difficulties of demonstrating a selective death rate bear witness to its reality!

Taking all this for granted, biologists must, it seems to me, face the duty of determining whether natural selection is a fundamental factor in evolution—in short of actually measuring the intensity of the selective death rate. The calipers are ready and their efficiency has been proved.

The duty to use them is imposed by ideals of good workmanship. "Measure that which is measurable and render measurable that which is not," is the ideal which has hitherto separated the precise from the descriptive sciences. It is the duty as well as the opportunity of the biologist of to-day to break down this distinction.

The duty to use them is imposed by the history of our science. For nearly half a century natural selection has been one of the chief problems of biology, and it would be cowardly for naturalists of this generation to leave the problem until a definite solution has been secured.

The duty to use them is imposed by the inability of the biologist to construct for himself a philosophical theory of evolution without natural selection as one of the factors. Yet the philosophical necessity of a given factor does not relieve the scientist from the duty of finding out whether that factor be a reality, and of measuring its intensity.

THE RELATION OF BIOLOGY TO AGRICULTURE

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UNTIL a few months ago Americans were inclined to express surprise at the paternalistic measures for fostering agriculture as adopted by other countries. Now, the necessity of ensuring adequate food supplies has made us willing to assume the same encouraging attitude toward agriculture as we have always held toward our manufacturing enterprises.

Last year we seemed broad-minded and liberal in what we were doing for the promotion of agriculture, and our motives were really largely philanthropic. We knew that the bulk of our population fared more sumptuously, if not more wisely, than the inhabitants of other nations, but it was maintained that the American laborer was the superior of the European, and his standard of living was, and must continue to be, a higher one. Now we would foster agriculture because we see our dependence upon that industry. The disposition to foster agriculture is evidenced by such actions as the legislatures' requesting the agricultural colleges to establish correspondence courses.

Although the meat boycott was heard of only in its organization, even that move showed plainly that either the standard of living or our agriculture must change. Doubtless both will be greatly modified.

It is not necessary to argue the urgent and immediate need of a more intelligent and scientific agriculture. Present prices are already inciting greater study, as well as adding to the numbers of farmers. The apparently diseased condition over which we have temporarily disturbed ourselves really exhibits nothing that can be readily treated except our tastes, and for those the treatment must be mainly psychological. That remedy is already at work, and the same conditions have also set at work the other remedy, of a more studied production.

It may be philanthropy, but it is also good economic policy, to do everything possible to distribute and add to our knowledge of scientific agricultural principles. The problem is to secure the intelligent application of what we have, but no less to increase our knowledge of principles and of their possible economic value.

The further we are removed from the unsettled times of 1862, the more clearly can we appreciate the wisdom of Justin Morrill in framing the law that founded our present agricultural teaching. The Hatch Act of 1887, by which our experiment stations were brought into exist-

ence, is of similar moment. Without the past operation of these two forces to ameliorate our present condition, the situation must have been much more serious.

Any discussion of the relation of any science to agriculture must center around these two institutions—the agricultural college and experiment station. The introduction into farming of improved business methods may be aided by these institutions, but their chief work has been, and will be, the interpretation of science to agriculture. Better business methods are being employed as the more scientific practises add to the attractiveness and certainty of the farmer's occupation.

A survey of the past is strongly suggestive of the idea that the greatest service of biology to agriculture has yet to be performed.

How Other Sciences have Influenced Agriculture

The indebtedness of agriculture to chemistry can hardly be estimated. It is only through the work of the chemist that we have accumulated our information regarding the elements of fertility and the needs of the various crops and their relation to each other and to different soils. No farmer reads the statement of analysis upon the fertilizer sack without thereby receiving immediate aid in the chemistry of his farming, and the greatest aid was given through the information that enabled him to make an intelligent choice of the fertilizer to be used.

To the bacteriologist we owe our understanding of the nature and successful cultivation of leguminous plants. The science of dairying, the handling of milk and manufacturing of milk products, is alike indebted to chemistry and bacteriology.

The physiologist has joined the chemist to qualify the farmer to convert his crops into animal products with the greatest economy, and new suggestive results of laborious investigation are constantly being added.

In biology, we find that horticulture is largely based upon botany. In fact, at the time the land-grant colleges were established, if we except perhaps the chemist, the botanists were the only scientists prepared to teach anything of direct value to agriculture. The knowledge of the origin and relation of varieties and their distribution and adaptability has enabled horticulture to become the most truly scientific of all branches of agriculture.

The service rendered in the study of weeds and devising methods of controlling them has been an important one in making for the fullest and best use of the resources in the soil. Botanists and horticulturists have also introduced many foreign plants of great value in the garden and in the field. As an example of this, we have the alfalfa plant, more recent importations of which seem likely to bring into use some western sections until now regarded as practically waste.

The main, if not the only direct service of zoology has been given through the subject of entomology. Although some of the most dangerous enemies of plants are still beyond control, such as the boll weevil, yet their habits are understood and the crops on which they prey can still be grown with only a fraction of the loss that would be sustained had the habits and life history of such pests not been made known. Other pests have either been eradicated or rendered so nearly controllable as to permit of our safely disturbing the balance of nature by devoting large areas to special crops of such plants as are not encouraged in the natural state.

The Zoologists' Inability to Aid Breeders

We should naturally expect zoology to throw considerable light upon the laws of heredity and upon possible methods of so modifying forms and functions of our animals as to give us more intelligent control of those great factors in agriculture. It is true that a most wonderful improvement of all classes of farm animals has been effected; from a few unpromising native stocks, numerous and distinct varieties have been evolved, each one having distinctive characters of value, either in special adaptability to specific conditions and systems of agriculture, or in capacity to yield a superior product, or, as is true of many breeds, combining some degree of excellence in both respects.

In this fascinating and valuable work, however, there has been little or nothing that could properly be called scientific, unless we should regard as science an accumulation of facts regarding occurrences the explanations of which have not been attempted by the breeders and not altogether successfully undertaken, as yet, by the zoologists.

The fact that zoology has given so little that could be utilized by the breeder is no reflection upon the zoologists. Their problem has been a difficult one, and until a science assumes a form of some definiteness, it is too early to expect any of its principles to be followed out into their operation in economic affairs, particularly when, as in zoology, supposed facts are being dethroned and the evolution of the science seems hardly begun.

The discoverer of important principles can not be expected to also assume the duty of interpreting his science to practise. He works for the acquisition of knowledge and the understanding of natural law in its broadest relations and is seldom qualified to give a scientific aspect to productive labors, even if willing to attempt such a task.

It can truthfully be stated that biology, as one of the sciences, is the newest and least definite of them all, unless we except, perhaps, psychology. This is not because great minds have not been occupied with it, for what other study has engaged such illustrious and widely-known men as Darwin and Wallace and Spencer and Galton and Huxley of England, and such as Lamarck in France and Weismann in Germany?

This retarded development has no doubt been largely due to the fact that biology requires all the other sciences as its servants, and it is only as chemistry and botany and physics and geology have progressed that the biologist has been able to find satisfactory data and material for his attempts to reveal the nature and origin of the various forms of life.

It is true that Darwin studied very closely the work of British stock breeders and referred largely to their work in his subsequent writings to explain and illustrate his theory of the origin of species through natural selection. The principal part of the constructive work of British stock breeders, however, had been done in the first half of last century, and the indebtedness of stock breeding to Darwin was by no means so considerable as the service that industry afforded to the naturalists of the time and to Darwin in particular.

It was not until 1859 that the "Origin of Species" was printed. Remembering, then, the revolutionizing aspect of the first reasonable explanations of the development of the forms of life, and the difficulties opposed to the general acceptance of natural selection as the main evolutionary factor, it is not very surprising that the economic value of such truth has received scant attention.

To interpret a science to an industry requires some individuals interested and qualified in both fields. If botany and zoology, in former years, attracted any men really conversant with agriculture, their full endowments have been devoted to some of the numerous engrossing and fascinating questions of pure science. So we find that until ten years ago it could scarcely be said that any scientific students of heredity were seriously attempting to serve agriculture.

The men who had done so much in the molding of animal form could not be called scientific; complete strangers to any conception of the physical basis of heredity they worked solely as directed by their own experience and such meager teachings as were obtainable from their predecessors. What little constructive work had been accomplished in the plant kingdom was effected by self-taught men of unusual natural endowments for the work.

It would be a serious mistake to lose sight of the fact that wonderful improvements had been effected by development and improvement of numerous varieties of both plants and animals long before any physiological explanation of heredity was attempted. It is quite clear, however, that the principles underlying the achievements of those earlier self-taught master breeders were very imperfectly understood as principles; indeed, it did not seem to them that a satisfactory explanation of their experiences could ever be forthcoming. Breeding was not an art based upon science, but was purely an artistic calling. This being true, it has been impossible to prepare younger men to

continue the valuable labors of best breeders, and the most gifted workers with plants and animals have been unable to impart to others the equipment with which they entered into their work. Their successors have been drawn from such men as possessed similar natural endowments and who happened to be so placed as to be encouraged to utilize their qualifications in the betterment of plants or animals, and plants and animals comprise all the objects and instruments of the agriculturist.

The Possibilities of Better Breeding

In our present solicitous and mercenary interest in agriculture, it is not needful to explain the desirability of in any way adding to the value and amount of the plant and animal products now coming from our farms. One paragraph from Mr. Burbank will suffice:

> It would not be difficult for one man to breed a new rye, wheat, barley, oats or rice, which would produce one grain more to each head, or a corn which would produce an extra kernel to each ear, another potato to each plant, or an apple, plum, orange or nut to each tree. What would be the result? In five staples, only, in the United States alone, the inexhaustible forces of nature would produce annually, without effort and without cost, 5,200,000 extra bushels of corn, 15,000,000 extra bushels of wheat, 20,000,000 extra bushels of oats, 1,500,000 extra bushels of barley and 21,000,000 extra bushels of potatoes.

Even more striking increases would be the result of an increase of one per cent. in the amount of human food that our animals now yield from the plants produced for them.

The past ten years have greatly changed the relation of biology to agriculture. One cause of that change was the growing need of special varieties of animals, and more particularly of plants, with such new combinations of characters as would especially adapt them to the economic needs of localities of peculiar conditions. Another factor was the great desirability of putting the subject of breeding into a more definite and scientific and teachable form than it had previously had. But the chief cause of the new era, dating from 1900, was the announcement of the wonderful truth embodied in what we know as Mendel's law.

Mendel's Law and the Influence of its Discovery

Mendel had finished his research and published his very striking results in 1865, when the world was too much engrossed with the Darwinian idea to take any serious interest in data derived from a few crops of sweet peas grown in a cloister yard by an Austrian monk.

In 1900, de Vries, of Amsterdam, and Correns, in France, working independently of each other and in ignorance of Mendel's paper, came to the same conclusion as had the pious monk of thirty-five years before, who, in thus having his name associated with his rediscovered findings, was more fortunate than some other scientists who have lived before their time.

The Mendelian law is concerned with the dominance and recessiveness of plant and animal characters. It was clearly shown by Mendel, and later by Correns and de Vries, that, given a single plant with a character we wish to perpetuate, among a hundred of that individual's grandchildren, there can be secured twenty-five that will be counterparts of their unusual grandparent, so far as the one special character is concerned. This percentage is obtained by mating the prodigy with ordinary stock and excluding the resultant hybrids from being fertilized by any but other produce of the same original unusual individual. Another twenty-five per cent. will be equally as capable of reproducing the opposite character of the individual from which they sprang. The remaining fifty per cent. appear true to the type of their hybrid parents, but, like them, reveal their actual identity when their offspring follow the same unusual proportions.

The fact that such proportions can be relied upon added a new feeling of certainty and greatly encouraged attempts to perpetuate and multiply various features of plants. Of course, in the first generation, the prized character of the parent may be recessive or prevented from asserting itself by the more powerful opposite, and, until it was known that one-fourth of the next generation might return to the character in question, many attempts to breed in new features were abandoned after the apparent failure of the first cross. Instances of the operation of the same law were found in the animal kingdom.

Castle found that in guinea-pigs the extra length of hair was dominant over short hair which reappeared in Mendelian proportions in the succeeding generation. Albinism and smoothness of coat were also found to be inherited as recessive Mendelian characters. But of even greater interest than these unusual proportions is the exhibition of inheritance by unit characters. When we see length of hair being inherited independently of its color, and each of these independent of arrangement as to roughness or smoothness, we begin to realize the vast number of unit characters that go to make up an organism.

The unusual proportions, occurring so nearly accurately in large numbers, were highly interesting to the biologists and very suggestive to many persons not previously interested either in botany or zoology.

Mendel's law was of the greatest importance in pure science because any explanation of the fixed proportions must be based upon the nature of the gametes, and much new theory and research was undertaken to ascertain the basis of such seeming unnatural exactness of proportion.

If we assume that the gametes produced by hybrid individuals are pure to one or the other of the parental characters, the explanation of the Mendelian proportions is comparatively simple. Such assumption, however, is not justifiable in the light of our present knowledge. A

satisfactory explanation of the basis of this law will be possible only after the discovery of several new facts regarding the behavior and identity of the component parts of the reproductive cells. This same line of research has also been suggested by the more recent development of our knowledge regarding the accessory chromosome. Such research demands the use of the most perfected instruments and the exercise of the finest technique. It requires an impartial and truly scientific mind, and it is, therefore, very gratifying to find that most of the facts being added to our knowledge concerning hereditary processes in these connections are furnished by American investigators.

The Optimism of 1900

Within a very few years, after 1900, numerous investigators found the Mendelian law to be operative for a wide variety of characters and in many species of plants. Evidence was also forthcoming to show that the same was true of some characters of farm animals.

The air was filled with expectancy, for, since so many things were known to be inherited by Mendelian proportions, it was quite generally assumed that all inheritance was of the same kind. Breeding was no longer an art, nor even a science, but a simple application of mathematics. True, our knowledge of the *modus operandi* of all these occurrences was incomplete, but Mendel's law appeared to be the key to all facts of inheritance, and nothing of moment could be unknown for more than a few months. Such was the thought of many enthusiastic persons in 1902 and 1903. It seemed as though the great door was soon to be unlocked and reveal to us the truth that should explain all inheritance and all life, bringing a new era in biology and in the many vital studies of man with which biology is so intimately connected.

But even should the scientific explanation of Mendel's law be slightly delayed, there was no reason for the breeder of plants and animals to remain under the old régime; so it seemed to many careful and earnest workers in agricultural lines. The fact that the derivation of the formula was obscure was no hindrance to its utility.

One outcome of the new thought was the organization of the American Breeders' Association. The membership of this association comprised botanists, zoologists, florists, seedsmen, growers of seed corn and other cereals, and also breeders of all classes of farm animals. The time was ripe for such an organization. It was the idea of some of the founders that the spread of the new science would revolutionize breeding practise.

At the second annual meeting of the American Breeders' Association, held in 1905, there were presented such papers as these: "Recent Discoveries in Heredity and their Bearing on Animal Breeding."

This paper was presented by Dr. Castle, of Harvard, a most capable

zoologist, though less acquainted than might be wished with commercial breeding.

Another paper was entitled, "Mendel's Law in Relation to Animal Breeding," and a third, "Heredity in the Light of Recent Investigations."

In the 1907 session of the same body, Mr. Spillman, of the Department of Agriculture, in a paper entitled, "The Chromosome in the Transmission of Hereditary Characters," said: "I believe that it will finally be possible to work out the complete relation so that we can get a full understanding of the behavior of hereditary characters and thus breed for improved forms with almost as much certainty as the chemist mixes solutions in order to produce a desired compound." At the same time and place, Dr. Davenport, of the Carnegie Institution of Washington, used these words: "Indeed, the fact that the enzymes of the germ cells, and particularly of the egg, determine hereditary characters, points the way to the modification of hereditary qualities and to the production of this or that character at will."

The expectations of such sanguine persons have not been realized. Considerable progress has been made, but it has been and bids fair to be more in the nature of a steady march than of a sudden flight.

Those who were most hopeful of the sufficiency of Mendelism overlooked three things: that we are not able to originate any specific character desired; that not all characters are transmitted in accordance with the Mendelian formula; and that, except for purposes of research, it is seldom practicable to breed for but one single or unit character at a time. Approved animal form embraces probably innumerable unit characters. So far, the only definitely known Mendelian unit characters in large animals are superficial ones, such as coat characters, which are of no direct commercial importance. The relation of the vital body characters is not understood and no capacity for useful functions has been shown to be a unit character. Even with the low number of three or four useful unit characters known to be Mendelian, the chance of their being combined in a single individual is so small as to be of no interest to a practical breeder.

The difficulties of perpetuating a character according to Mendel's law are much less serious with plants than with animals. Knowing that there is strong probability of a unit character of a plant's being Mendelian, the certainty regarding the rate at which it may be propagated adds greatly to the attractiveness of plant breeding and greatly stimulates the search for and endeavor to produce valuable variations.

The Breeders and Mendel's Law

Mendelism has, therefore, given considerable immediate aid to economic plant breeding. It has served to interest seed growers in biology

—rendering their work more intelligent and more scientific and consequently much more valuable. It has also drawn the attention of scientific workers to economic questions, and encouraged research, planned with some thought for economic interests and yet highly scientific.

Animal breeding has been influenced by Mendelism, chiefly through indirect means. The practical obstacles to rearing of large numbers of animals for the chance of finding some new thing has compelled animal breeders to go at a much slower pace than that set by the plant breeders. The fact that some characters of minor practical value have been shown to be inherited in definite proportions has stimulated an interest and study in other aspects of heredity that explains otherwise mysterious occurrences and dissipates common unscientific ideas that have done much to hinder real progress. Ten years ago when the possibilities of breeding up our farm crops were becoming apparent the accomplishments of breeders of animals were the incentive and patterns for those working with plants. To-day the situation is reversed, and work with plants is seen to be beset with fewer practical difficulties and productive of much earlier returns than equally skillful work in the animal kingdom.

The Question of Transmission of Results of Environment of no Interest to Breeders

Breeders and biologists are still far from unanimous in their opinions of the relation of environment to heredity. This fact is no serious hindrance to the breeder's work, however, except in so far as the heat and confusion which is the main product of discussions of the actual rôle of environment, require energy that could be more profitably utilized in some other way. Although a settlement of the question might permit a clearer conception of heredity and facilitate scientific inquiry, it could call for no considerable change in breeding practise. The majority of animal breeders firmly believe that the effects of environment are transmitted. Mr. Burbank also believes the same of plants; but neither Mr. Burbank nor any animal breeder has attempted a physiological explanation of such claimed occurrences. It is immaterial whether we emphasize environment or selection as the chief factor in the production and maintenance of variations. Both are essential, and to consider the changes in our domestic animals to be the outcome of artificial selection, aided and facilitated by adjusted environments, is quite as satisfying from the breeder's standpoint as ascribing first place to environment. Reliance upon selection, however, has the present advantage of being more nearly explained physiologically than is the other view.

Breeders of to-day, especially plant breeders, recognize more clearly

than formerly the dependence of improvement upon the ability to detect and to judge the value of departures from the common types of our commercial plants. This means a greater attention to the study of form and characteristics as a basis of and preparation for work along breeding lines and suggests the need of qualifications of an artistic nature. It was because of natural love for animals and unusual insight into animal life and form that a comparatively few men have been able to establish more than threescore breeds of animals of highest efficiency in the performance of a variety of functions through which the human race is served.

The Principle Involved in New Plant and Animal Creations

It is not necessary to enumerate the accomplishments of Mr. Burbank. Through the magazines the public has already been given an adequate if not an exaggerated account of the achievements of that wonderful man. It is a matter of immediate concern to every one to know the basis of Mr. Burbank's success. Has he secrets which are to die with him? Or are we to have numerous workers to whom life forces are as plastic clay? Do his accomplishments prove to us the economic value of recent scientific work or do they refer us back to principles and methods always known but lightly regarded in our eagerness to grasp ideas announced as sure to supersede all that has gone before?

The answer to these questions interests the workers among plants, and no less the student of animals, because the laws of inheritance are, to a large extent, alike in both kingdoms. To most biologists and breeders the greatest value of Mr. Burbank's work lies in the light it throws upon inheritance and the encouragement it offers to persons whose natural leanings prompt them to identify themselves with commercial or scientific work with plants or animals.

The best opinion seems to be that the effect of Mr. Burbank's work will not be to revolutionize breeding practise, but that it does mark an important step in the complete adaptation of plants and animals to all the needs of man. It does this by demonstrating what may be done in the light of knowledge that has been always with us, but seldom appreciated.

Professor Kellogg, of Leland Stanford University, a biologist of standing, and quite intimately acquainted with Mr. Burbank and his work, writes of it in these words:

> No new revelations to science of an overturning character; but the revelations of the possibilities of accomplishment, based on general principles already known, by an unusual man. No new laws of evolution, but new facts, new data, new canons for special cases. No new principle or process to substitute for selection, but a new proof of the possibilities of the effectiveness of the old

principle. No new categories of variations, but an illuminating demonstration of the possibilities of stimulating variability and of the reality of this general variability as the fundamental transforming factor. No new evidence either to help the Darwinian factors to their death-bed, or to strengthen their lease on life, for the "man" factor in all the selecting phenomena in Burbank's gardens excludes all natural factors.

Most of Mr. Burbank's creations are originated by the crossing of existing forms. In a large number of hybrids there is almost a certainty of their being some chance individual of useful character. "In one year he burned up 65,000 two- and three-year-old hybrid seedling berry bushes in one great bonfire, and had fourteen others of similar size."

About the same time that the Mendelian law was rediscovered the word mutations came into use, and it is such a useful word that it is now widely used outside of biology. The fact that plants and animals produce distinctive characters not connected with the ordinary form by intermediate stages is perhaps of greater importance than any other announcement since the publication of "The Origin of Species." Although in a sense opposed to Darwin's conception, the examination of the change in species through mutations as given by de Vries would, in all probability, have been most warmly received by Darwin, because it is a reasonable amendment to his maturest attempt to enunciate the laws of nature.

The fact that mutations do occur, and that they may properly be considered the foundation of elementary species or varieties, as shown by de Vries, is of the highest economic significance. It is only through procedure based upon this principle that lasting results have been obtained by even the most careful selection and improvement of farm crops. Because of the violation of this principle, much conscientious effort has failed to originate even a single variety of lasting value.

We now recognize that in the creations available we have the beginnings and the possibilities of all we seem likely to want or need in the way of new varieties or types of plants or animals.

From a field sown with a supposed pure variety of Swedish barely, Nilsson has isolated and established a number of separate and distinct types, each one having some features of utility that renders it superior to the crop formerly grown in the locality for which it was designed. Here, too, the "man" factor was the chief factor. Nilsson's work especially suggests that the beginnings of all we need are to be found by those who have the skill and the diligence to detect and use them.

In a similar instance, a worker in an American experiment station has isolated a number of types of cotton of distinct usefulness from a field of what had been regarded as a standard variety.

This conception of the origin of varieties emphasizes the single in-

dividual rather than the group, and necessitates such intimacy with plant or animal form as will qualify the breeder to recognize and utilize the wealth of material always at hand. And it may also be said that it was only when, through a recognition of this principle, plant breeders began to emulate animal breeders by basing their work upon the individual rather than the group, that lasting results were forthcoming.

This conception also places within the reach of every farmer the means of developing varieties of field crops possessed of characters of especial adaptability to his own land and looks toward more numerous seed farms and the almost negligible difficulty in securing for each field the seeds of varieties of maximum value and productive of maximum yields.

Although the occurrence and use of mutations are less fully understood in animals, it affords a sensible explanation of the most of the progress of animal breeders, and clearly shows that after all, even to a greater degree than we had ever before realized, our chief dependence is upon the exercise of the "man" factor, in detecting and properly estimating the possibilities always available to those who truly desire and are qualified to use them.

Agriculture consists of dealings with plants and animals. The nature and behavior of a plant or an animal is determined and controlled by its inheritance and its environment. Heretofore, the inheritance has been but little understood and interest and effort have centered chiefly around environment. The possibilities of that factor and the possibilities of profiting by its control have therefore come to be well understood. Considering this, it is not strange that the other factor, of inheritance, being little understood, should often have been regarded as of minor importance.

There is still much to be added to our knowledge of inheritance, but the new light of the past decade shows that the man factor at work in directing inheritance may be at least equally as productive as when applied through environment.

It is unsatisfactory to attempt to indicate how the use of this newly perceived power will be evidenced.

The Use of More Definite Knowledge of Heredity

The greater attention to the securing of varieties of crops that give maximum returns of maximum value will add greatly to the productiveness of our lands, and the increase of yields can be supported by soil resources now going to waste; the effort to raise yields by this means will encourage such interest and study as must precede intelligent conservation. It does not seem likely that new creations will occur in field agriculture as have been produced in horticulture, though our knowledge of the origin and inheritance of characters is already being

utilized to develop such new varieties of old species as will be adapted to the alkali and semi-arid and otherwise unproductive areas, and thus add greatly to the production from large areas that can never hope to be brought under irrigation.

The securing of seed to produce maximum yields is a matter that has to be canvassed for each particular field and for each particular type of farming necessitated by local conditions governing production and marketing.

In the animal kingdom the new conception of heredity may produce new strains and new breeds to meet newly created demands, or to meet the requirements of localities not fully served by existing types.

The length of time between generations of animals, and the great number of characters that must be considered make it appear that animal breeding, even more than plant breeding, must still remain an art. It is as true to-day as when stated by Darwin fifty years ago, that,

> not one man in a thousand has accuracy of eye and judgment sufficient to become an eminent breeder. If gifted with these qualities, and he studies the subject for years, and devotes his lifetime to it with indomitable perseverance, he will succeed and may make great improvement. If he wants any of these qualities, he will assuredly fail.

It is not in the appearance of eminent breeders, however, that the greatest hope of the future lies. Most of our past progress has been effected as a result of the distribution of surplus stock of eminent breeders, who knew nothing of the science upon which their work was based. Naturally gifted breeders of the future will be able to accomplish still more, because, as a result of study, they may come to have the proper appreciation of fundamental facts which they could otherwise have attained only by experience extending over a large part of the periods of their activities.

In both animals and plants we may look for advancement through the elevation of the best existing types, but a still greater economic advancement may be expected through the discarding, by the majority, of their inferior stock, in order that they may procure the instruments of greater worth, and so emulate the practises of the more progressive of their acquaintances.

This progressive attitude will come as a result of the more general and the more practical appreciation by the many, of the faith in heredity and selection that has been the cornerstone of the success of the few in the past. It will be accomplished by the spread of biological knowledge concerning heredity. It is true that that knowledge is in imperfect form and that we are still unable to originate what we desire, but such significant facts as are fully established shed sufficient light to dispel the darkness and mystery that still prevent over ninety per cent. of our farmers from entertaining that conception of the influence of heredity that is essential to good economic practise.

The greatest service of the biology of the past decade consists in having placed the science of the rearing of plants and animals in good pedagogic form. The placing of the art of breeding upon a teachable, scientific basis, and the realization of what is possible through the fullest exercise of the man factor, gives a very hopeful aspect to the agriculture of the future.

It is to be regretted that our students of heredity and our breeders are not in closer touch with each other. Though the responsibility for this lack of intimate association rests with both parties, I am inclined to think that the biologists are most at fault. In the first place, some of those most sanguine of a complete revolution in breeding practise destroyed what confidence the agriculturists had in them by extravagant and unwarranted predictions and by recommendations that were altogether impracticable. Following this extreme optimism, the same men, during the past few months, have evidenced a pessimistic attitude and, what is worse, have not refrained from expressing their reactionary ideas to the people who were beginning to share some of the former optimism. These pessimistic utterances are based upon data concerning supposed non-inheritance, which data, when not rejected by the practical breeder, are to him suggestive of contrary conclusions. This unfortunate condition is attributable to the disposition of the teachers to discuss the higher debatable points with pupils who have not yet had time to master the elements.

Since the passage of the Adams Act in 1906, much new work has been inaugurated that has for its object the establishment of the right relations between science, and especially biological science, and agriculture. Some of the experiment-station projects have yielded principally negative results, but are none the less valuable on that account. More and better trained workers are needed, and this fact will no doubt bring to the aid of biology and agriculture many capable workers such as have heretofore been discouraged by the lack of opportunities to make themselves useful in this field.

"The achievements of 'pure' science in one generation constitute the formulæ of the 'applied' science of the next." These students of applied science are also certain to be of great service to pure science. Some of the most valuable scientific conclusions have been derived from the results and carefully kept data of experimenters engaged in work carried on for commercial advantages. Continued additions to the science, as worked out into their applications, will continue to modify farm operations.

But it is not alone through agriculture that the world is increasingly indebted to our biologists. If ninety per cent. of our farmers are hampered in their work by their present ignorance concerning heredity, it can be said with equal truthfulness that over ninety per cent. of our

entire population live less intelligently and therefore to less purpose than they might live if, for the almost complete ignorance of the hereditary processes there could be substituted a reasonable conception of the things that connect the individual with his ancestry and which show that the welfare of the race, while advanced by the improvement of the individual, is still of greater moment than that of any one individual, and conditions which are seriously detrimental to the individual are not infrequently beneficial to a large number of the race.

The American Breeders' Association is an organized agency working to bring human needs and industries into more intimate relation with the fundamental science of heredity. One branch of the work of this association, of vital importance to the nation, has been given some prominence in late magazine numbers. This is the study of human inheritance as carried on by the association's committee on eugenics.

The objects of this committee are "to investigate and report on heredity in the human race; to devise methods of recording the values of the blood of individuals, families, peoples and races; to emphasize the value of superior blood and the menace to society of inferior blood; and to suggest methods of improving the heredity of the family, the people and the race."

The personnel of the committee is a guarantee that the matter will be thoroughly studied and that there will be no premature recommendations of legislation. David Starr Jordan is the chairman of the committee and Professors C. B. Davenport, Castle and Kellogg are among the members. Their plan is to first study the situation and effect a reform in the tabulation of vital and social statistics, then to work for the education of the race upon the facts of human inheritance. The situation is well expressed by the secretary of the committee in a recent publication:

> A *new* plague that rendered four per cent. of our population, chiefly at the most productive age, not only incompetent but a burden costing one hundred million dollars yearly to support, would instantly attract universal attention, and millions would be forthcoming for its study. . . . But we have become so used to crime, disease and degeneracy that we take them as necessary evils. That they were, in the world's ignorance, is granted. That they must remain so, is denied. Vastly more effective than ten million dollars to "charity" would be ten million to eugenics. He who, by such a gift, should redeem mankind from vice, and suffering, would be the world's wisest philanthropist.

IS EUCLID'S GEOMETRY MERELY A THEORY?

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AS there are creeds in religion, so there are creeds in geometry. Most of us pin our faith upon Euclid, whose masterpiece of reasoning is still, after twenty-two centuries, the wonder of the world. The system that Euclid founded stands, as it were, four-square and solid; it meets every need in the only kind of space that we practically know. Over against this edifice, the modern geometries of hyperspace have been reared, from foundations which we Euclideans regard as fantastic. They are intangible structures, like the towers and battlements of a region of dreams.

The present writer holds no brief in favor of a fourth dimension of space. Hypothetical realms, wherein the dimensions of space are assumed to be greater in number than three, yield strange geometries, which are only card-castles, products of a sort of intellectual play, in the construction of which the laws of logic supply the rules of the game. The character of each system is determined by whatsoever assumptions its builder lays down at the start. The illustrious Euclid himself, whom none would rank as visionary, would probably set no great store by these hypergeometries. If he were to return to earth to-day, his interest in them would be that of a retired chess-champion who perceives that his old style of play has given rise to new varieties of the game. Nothing from out this fairyland of thinking could endanger Euclid's prestige; he might contemplate retirement on a professor's old-age pension.

Nevertheless, as soon as Euclid had viewed modern geometry throughout its entire range, the mere suggestion of a pension would in all likelihood ruffle his spirit. For by that time the master would know that geometers no longer blindly accept his teachings; that, moreover, our real space holds mysteries of which he never dreamed. When finally he should discover that experts have arisen who would undertake to instruct him at his own game, he would investigate the massive non-Euclidean systems—the Lobachevski-Bolyai or pseudospherical geometry, and another, the spherical, invented by Riemann—no mere card-castles, but valid in their application to every known space-condition of the universe. Like the rest of us, Euclid would ask himself: In which of these varieties of space does our actual universe belong?

Now, Euclid's geometry is, of course, something more than a game. Its rules—the twelve axioms and five postulates—taken as a group, Euclid might well be proud of. Most people believe that the whole body of his proof rests upon them as upon an eternally established foundation. Eternity is too long to contemplate, but we are certain that to the present time, in no instance, have these seventeen assumptions, when correctly used, ever led to a detectable error. His reasoning is always consistent in itself, always in perfect accord with the known laws of mechanics. One does not feel that the system is a Mahomet's coffin, hovering unsupported in mid-air; it seems to rest on the solid earth, and very firmly. Where, then, is any weakness in the foundation that he laid?

Possibly, in his sleep through the centuries, Euclid has turned over once or twice at doubts, first raised by Ptolemy in the second century A.D., who never became quite convinced that a certain momentous statement was perfectly self-evident, a statement which Euclid used without proving. Apparently it was an afterthought with Euclid in the first place, for not until he had reasoned himself well into the heart of his subject did the need for it, or for something like it, become imperative. Then he asserted quite dogmatically that: *Through the same point there can not be two parallels to the same straight line.* Ptolemy, hoping to strengthen Euclid's foundation, tried to prove this parallel postulate, but concerning the outcome, Poincaré, about eighteen centuries later, has recently said: "What vast effort has been wasted in this chimeric hope is truly unimaginable. Finally, in the first quarter of the nineteenth century, and almost at the same time, a Hungarian and a Russian, Bolyai and Lobachevski, established irrefutably that this demonstration is impossible; they have almost rid us of geometries 'sans postulatum'; since then the Académie des Sciences receives only about one or two new demonstrations a year."[1] The parallel postulate, then, is a weak spot in the Euclidean system. The demonstration that beyond all doubt no proof of its correctness can be devised was an epoch-making discovery. Bolyai's share in this event took concrete form in a brief appendix to a work by his father, published in 1831. Halsted characterizes this document as "the most extraordinary two dozen pages in the history of human thought."

Our chief concern for the next few moments will be to comprehend why the truth of the Euclidean postulate can not be established by argument. After that, I shall try to show why it is not self-evident. These steps taken, I believe that the reader will agree with me that, since it can not be proved, one may freely choose some other postulate in its stead, and thus develop a different geometry every whit as trustworthy.

[1] Poincaré, "Science and Hypothesis," transl. by G. B. Halsted, p. 30; where a clear account of these geometries will be found.

Let no one suppose, however, that the least dispute has ever arisen as to what parallel lines are. Euclid defined them as: Straight lines which are in the same plane, and which, being produced ever so far both ways, *do not meet*. All geometers accept this definition, just as at whist every one agrees on the meaning of certain terms—calls a spade a spade, and so forth. To the brilliant young Lobachevski no good reason presented itself why through a given point there should be only one such parallel to a given straight line. He accepted all Euclid's assumptions except this one, in place of which he substituted a contradictory statement of his own making; he hazarded the novel assertion that: Through a given point there *can be two parallels* to the same straight line. On this foundation he erected a new geometry, building proposition upon proposition until he had reared an edifice as coherent and in every respect as perfect as the geometry of Euclid. What conclusion may we draw? This: had Euclid's postulate been eternally true, then to deny it while holding to his other axioms would have led Lobachevski into endless inconsistencies. But the fact that its contrary

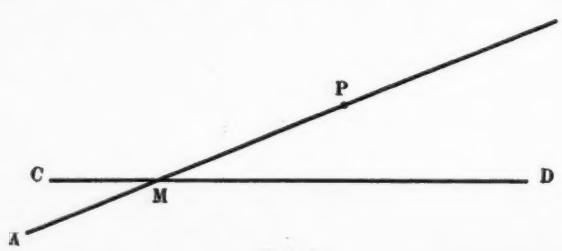

FIG. 1.

was substituted for it and a new geometry developed without encountering any logical obstacle shows that the postulate rests on nothing more fundamental than itself; shows that it swings, so to speak, in mid-air, unaffected by Euclid's other assertions. No statement can be proved by itself alone; consequently, this statement, having no logical connection with any other, can not be proved at all. Moreover, this achievement, broadly comprehended, set the entire Euclidean system aswing without support; its supposed connection with the solid earth was a fact only of the imagination.

I promised, in the next place, to show that Euclid's postulate lacks self-evidence. In Fig. 1 there is a point *P*, lying without a straight line *CD*. Another straight line *AB* passes through this point, and we shall imagine both *AB* and *CD* to be produced ever so far both ways.

Now *AB* will be parallel to *CD*, if they conform to Euclid's definition of what parallels are, namely, if both lines are straight, and in the same plane, and being produced indefinitely, do not meet. In that position the lines would be parallel, but let us start from the position

shown in the figure, where the lines we are talking about do meet at the point *M*, and let us imagine further that this point of intersection *M* travels along the line *CD*. If then we keep turning the line *AB* slowly round the point *P*, eventually the point of intersection *M* must disappear at one end and reappear at the other end of *CD*, it matters not how far the two lines have been extended.

The assumption hidden in Euclid's assumption is that there can be one and only one position of the moving line *AB* at which it will be parallel to *CD*. Lobachevski contrariwise assumes that *AB* will have to be turned through a finite angle *after* parting from *CD* *before* it intersects with *CD* again. That angle to be passed through gives Lobachevski the opportunity of postulating not only two parallels to *CD*, but an aggregate of parallels, all passing through the point *P*. The same argument may be presented a little differently and more clearly perhaps, as follows: Imagine *AB* at first not merely parallel but at all points equidistant from *CD*. Will not *AB* have to dip through a certain distance before it can meet *CD*?[2]

This problem, apparently so simple, is of such a nature that neither opponent can prove his assertion. It will be observed that when Euclid says only one parallel is possible, and when Lobachevski says an infinite number of them are possible, there is still room for a third champion who will say no parallels are possible, that the lines *AB* and *CD* if extended will always meet, which is precisely Riemann's position on the question. The three geometries are thus exactly upon a par; no one of them can establish itself against the other two; and the number of possibilities is complete, for among the assertions "one," "many" and "none," there is no position unoccupied in reference to the mystery of parallel lines; no chance left for any fourth geometry on this basis.

We are now on the threshold of non-Euclidean geometry, prepared, I trust, to enter a new variety of space where geometrical problems work out to results differing widely from those found in the books of Euclid. Compared with Lobachevski, Euclid was more sparing of parallels, and the effect of this parsimony upon Euclid's idea of space is very marked. I know of no better expression for the difference between their notions of space than to say that Lobachevski's space is *roomier*. In Lobachevski's space, if a man whose course was restricted to a perfectly straight line should wish to avoid crossing a perfectly straight road,

[2] Nothing in the definition, as established by Euclid himself, compels one to believe that two parallel lines must be equidistant. The requirements are that they be straight, that they lie in the same plane, and that they do not meet. Euclid discovers that his parallels are at all corresponding points equidistant from one another; but his parallels are peculiar in this respect, and it should be borne in mind that they owe their existence to the postulate which no one can validate.

he might set out in exactly the same direction as the road runs, or he might incline a very little toward it; in either case he would never meet it. This is equivalent to saying that Lobachevski's space is more expansive, more generously given, and if the reader will follow me a step further, I may say that this space becomes roomier increasingly with every step that the man takes forward.

It costs nothing to imagine ourselves entering this domain of Lobachevski; indeed, for aught we know, we may be actually in it now. And it will cost us no more to imagine our expedition equipped with instruments for measuring angles and for drawing straight lines, instruments more delicate and accurate than any that science has yet devised. A series of experiments may then be carried out to illustrate the properties of this hyperbolic region. I shall limit the narrative to some of the results we could obtain:

A. Parallels, really straight lines that never meet, have a point of nearest approach to each other, but if followed in either direction outward from this point, they will be found to diverge, spreading farther apart without limit (Fig. 2).

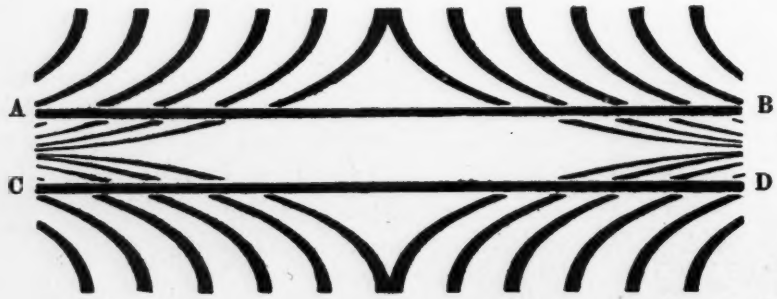

FIG. 2. The lines *AB* and *CD* are straight, as may be seen by viewing the figure from one side with the eye close to the paper. They are in the same plane and will never meet. Yet by an optical illusion we here obtain within a small compass the same appearance as would be furnished by two parallels to an eye located in Lobachevski's space and capable of surveying a tremendous stretch of the parallels from a very great distance. The diagram probably has no reference whatever to non-Euclidean geometry. It elucidates mental, not physical, phenomena.

B. If two perpendiculars are erected on a Lobachevski parallel, they will spread away from each other, becoming farther apart the farther we extend them outward from the base line.

C. With this base line and the two perpendiculars, we might think we had three sides of a rectangle, but no—for after making three of the corners right angles, the fourth must needs be an acute angle. A true rectangle is impossible (Fig. 3).

D. We can, however, draw a straight-sided triangle. In Euclidean space the internal angles of such a triangle, added together, always equal two right angles, but here they fall short of two right angles, and

the larger the triangle, the less the sum of its internal angles. Logically pursued, the largest triangle possible would have all its sides parallel and all its angles zero.

This last statement has touched the verge of infinity and that is no doubt treacherous territory. Coming back to our real universe—How can we prove that Euclid is right about it? The real universe is large. If, like the adversary in the Book of Job, we could go to and fro in the great world and walk up and down in it, then we might decide the controversy. But the limit of man's present astronomical measurements is only about 30 light-years—176 millions of millions of miles. Within this compass he has observed no drift or change in the direction of rays of light. If in our real space parallels are not exactly and everywhere equidistant, Euclid's geometry is incorrect. The slightest deviation in parallels would give the victory to Lobachevski or else to the third competitor, Riemann. The three justly claim equal con-

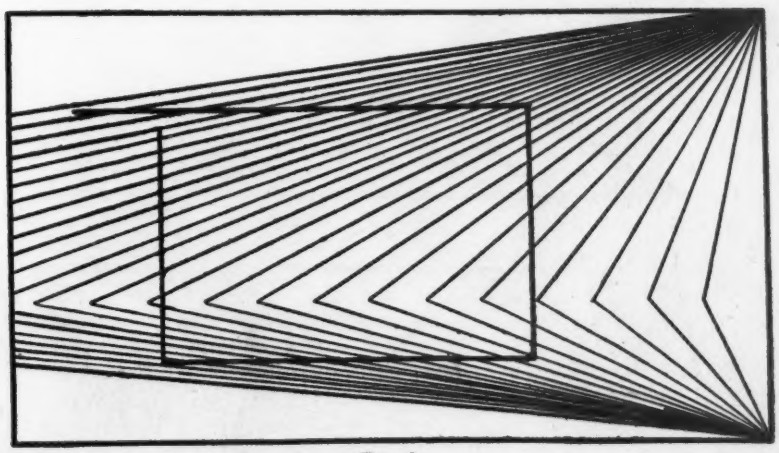

FIG. 3.

sideration in the light of present knowledge. Could such drift, if real, escape human observation? Yes; first, because our instruments are not absolutely accurate; and secondly, because eyesight is no infallible test.

If the human eye could survey a sufficiently tremendous expanse, then parallels running through it might present the appearance of the hyperbolic curves limiting the black and white areas in Fig. 4. These curves may represent, and in certain respects they do simulate, the parallels of Lobachevski. They are, to be sure, not parallels, for parallels are by definition straight; however, by placing the eye an inch and a half above the center of this figure, these lines can be made to look straight—a fact that confirms the statement that eyesight is not an infallible test of straightness.

Fig. 4 will do good service if it enables us to understand what people mean when they assert profoundly that "non-Euclidean space is curved." We ought to discard this misleading, though very prevalent, expression, for it is as confusing as to say that space is straight, or cold, or pink. It certainly sounds absurd to call a straight line curved under any circumstances, and so it is, so long as we confine our thinking to any one kind of space. But in carrying lines over from one space to another, there is this change of emphasis. For example, the parallels of Lobachevski, when transferred into Euclidean space, cease to be parallels and become, as shown in Fig. 4, hyperbolic curves.

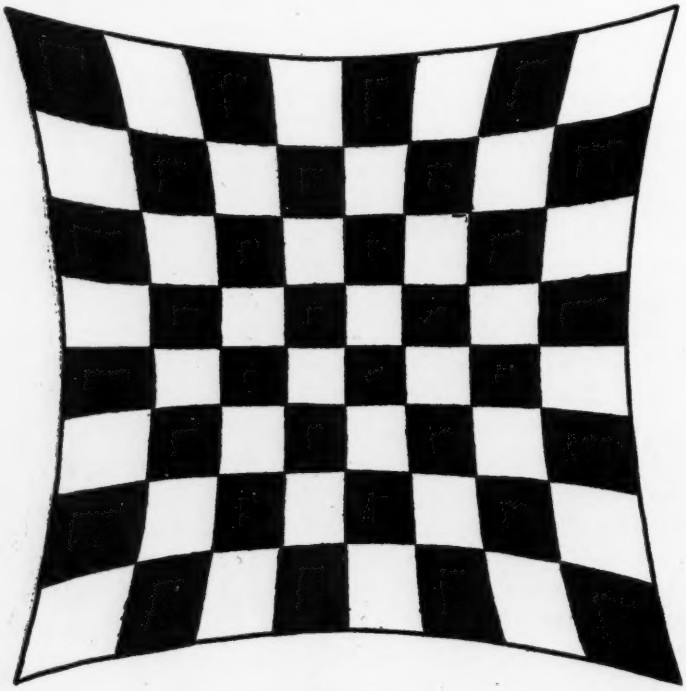

FIG. 4.

Contrariwise, the parallels of Euclid, transferred into Lobachevski's space, retain merely their secondary property of equidistance, and pass under the name of equidistantials, since they are no longer true parallels, nor even straight, but rather they are very long curves.

We read in the Arabian Nights of the magical carpet of Tangu, which could be made to fly incredible distances by wishing it to do so. Imagination can furnish us with a similar carpet that will flit from one realm of space to another. Suppose then that our carpet is being woven at a non-Euclidean factory. It should be pliable, but it must not stretch, and it must possess truly princely size, having leagues upon leagues of surface. When spread out, it must lie perfectly flat and

smooth in Lobachevski's space, but if transported into Euclidean space, it can only lie crinkly and fluted around its edges, for this environment, though boundless, is less roomy and the expanse will be too niggardly to accommodate the carpet's ample proportions. Suppose, in addition, that the carpet, while at the non-Euclidean factory, receives on its surface a checker-board pattern of black and white squares separated by criss-cross parallel lines, truly straight lines in the sense of being the shortest distances between points. The squares can not be perfect rectangles because, as already observed, such figures are not among the non-Euclidean possibilities. In Euclidean space, they would look like the black and white areas in Fig. 4. The figure is not, however, a perfect representation, because the carpet could not be made to lie flat in Euclidean surroundings without violent stretching, while to distend it would be to destroy the spatial relations of the lines of the pattern, after which, for geometrical purposes, it would no longer be the same carpet.

Spread out the carpet, nevertheless, as evenly as Euclidean space allows. No part will lie perfectly flat, of course; and only a limited portion can be made to lie smooth; the outlying portions will refuse to be spread out and must remain in folds. The smooth portion will then be slightly curved into the shape of a saddle, trending upward at front and back, and rolling off downward on either side, the whole forming a surface of constant negative curvature, called by mathematicians a pseudosphere, and being simply Lobachevski's plane surface after its transportation into the Euclidean environment. Upon such a surface we can draw diagrams suited to illustrate any problem in Lobachevski's plane geometry just as for Euclid's plane geometry we make use of the flat surface of a blackboard. Lines drawn on the pseudosphere can not be straight; they can only be the *straightest* lines that the surface will allow; but, limiting our discussion to lines lying wholly within the surface, these straightest lines will still be the shortest distances between points in the surface and would remain so, even if the surface were crushed into a wrinkled heap.

We do not know upon what kind of a surface Euclid drew his diagrams, perhaps upon sand, but it is reasonable to presume that it was approximately flat. Had he used a pseudospherical surface, he might have developed a different conception of space. Had he, on the contrary, chosen a sphere, he might have arrived at the geometry of Riemann, for the plane surface of Riemannian space becomes simply a sphere under Euclidean conditions. The opportunity is so favorable just now that I may be permitted briefly to set down some of the results derived from this third type of geometry. Obviously, the straightest line that one could draw upon a sphere, as, for instance, by stretching a string between two points on the surface, would, if extended, go completely round and form a great circle. Certain conclusions follow:

A. No parallels are possible; all great circles (straightest lines) must somewhere meet.

B. Euclid's axiom that: *Through any two points only one straight can pass,* is, in most cases, correct; but when the points chosen are diametrically opposed, as are the poles of the earth, then an infinity of great circles cross at such points, and any two of these lines enclose a space.

C. Concerning triangles, the internal angles are together always equal to *more than* two right angles, the excess increasing with the size of the triangle. Rectangles are impossible. Two plane figures (except circles) can not be similar in shape unless equal in size.

D. The Riemannian space is not infinite in extent, but returns into itself. It is, however, boundless; one could never come to the end of it. With eyes adapted to enormous distances a creature looking in any direction might see the back of its own head.

E. On the hypothesis that our own universe is of this nature, "a finite number of our common building bricks," as Halsted says, "might be written down which might be more than our universe could contain." And if our earth should increase in bulk, at last the lower surface would advance upon us from above, and, reaching us, would fill the whole universe.

It is commonly supposed that these peculiarities of Riemannian space are easier to conceive than are the results at which Lobachevski arrives, but this is probably not the case. Long ago, Beltrami discovered that the whole space of Lobachevski, notwithstanding that it is infinite in extent in all directions, can be conceived as packed within a hollow globe of finite radius. Imagine, therefore, a great sphere of a hundred yards' radius, with a door leading into it. Looking in, let us suppose that we can discover a railroad track on a trestle extending from the doorway diametrically across to the other side, and a small man—an inch high—standing between the rails and at the exact center of the sphere. Nothing about this view suggests anything but ordinary space to us; it is only for the little being at the center that this enclosure constitutes Lobachevski's universe.

Another assumption is now to be granted: let the man dwindle in size whenever he moves out of the center toward the shell of the sphere. Growing less and less, he would have no size at all upon reaching the shell, but he *could never reach it,* for the length of his stride would lessen in proportion to his lessening stature. To him, therefore, the sphere is infinite in extent. Likewise all other objects—the boards on the footpath, the foot-rule and the keys in his pocket, and the pocket itself—have their sizes determined by their location within the sphere, let only the rails of the track be continuously parallel both according to his and our own notion of things, and also according to Euclid's definition.

Going to and fro along the track, the little man would judge that the rails are not equidistant at all. Applying his shrinkable foot-rule, he would decide that the space between the rails varied in width at different places. He would come to the same conclusion that we have set down, namely, that parallels may at first approach but, following them further, they diverge more and more. All this he would discover and never suspect that his own variable dimensions were the cause of a deception, for would not his surroundings shrink always in proportion to himself? Beltrami's illustration thus attains its purpose by making solid objects expand and contract in place of allowing space itself to grow any more roomy than our Euclidean notions permit.

If Euclid were to return to earth to-day, he would find many geometries, but the three here described would probably interest him above all others. A fitting task for Euclid would be to coordinate this trilogy of systems. With the three volumes spread open before him, he could write a dictionary by the aid of which a student could translate any proposition stated in one volume into the corresponding proposition given in either of the other two. It is at bottom a matter of words, or at least the facts lend themselves to that interpretation. With intense satisfaction Euclid could still contemplate his own geometry. Where long and involved phrases are necessary to convey the idea presented in the other systems, his own ideas are always lucid and tersely expressible. His system is consequently by far the most *convenient,* so much more convenient, that if we should ever discover any discrepancy between it and the facts of the physical universe, we would probably prefer to change our laws of physics or mechanics rather than to adjust ourselves to a less convenient system of geometry.

THE UNDERLYING FACTS OF SCIENCE

By ALFRED SANG
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SCIENCE originated in the temple; for ages it remained as a mass of detached observations floating in mysticism. The civilization of Greece gave us the broad lines of many of the sciences, but the confinement of knowledge to monasteries, the enslavement of the human mind and the suppression of the wisdom of the ancients during the dark middle ages, deferred the rise of science until within comparatively recent times. From mysticism science has gradually drifted into agnosticism; mysticism cramped the work of the investigator; agnosticism lays no restraint whatever on his mental ambitions. The suspension of judgment on all matters unproven has helped in mighty measure to make theory the indispensable weapon of the scientist in attacking unsolved problems.

The Value of Theory

Theory, based on observation, is an accepted factor of inquiry, and the temporary acceptance of a theory serves as a scaffolding in the building up of knowledge; it is necessary to the work of correlating facts and to train the mind for the discovery of new facts. When we find our theories checked and kept within certain definite bounds, we can assume that we have found the measure of our ignorance and that the truth lies somewhere within the compass of these theories. If a theory is not a logical deduction from facts it should be called a hypothesis.

Nothing has created more prejudice, and thereby done more harm to theory as an instrument of progress, than the easy acceptance by the general public of all novel and sensational theories as proven facts if consecrated by the daily newspapers and the magazines. From the husk of the acorn an oak is postulated, although it may be rotten at the core and worthless. But we *must* theorize because we are built that way. As Tyndall once said:

> Man is prone to idealization. He can not accept as final the phenomena of the sensible world, but looks behind that world into another which rules the sensible one.

The Limits of Conception

In scientific speculation, it is essential that we lose all sense of proportion, of time and of space. No dimension must appear impos-

sible because it is infinitely large or infinitely small; no time must seem impossible on account of its infinite length or of its infinite shortness; the grains of sand of the ocean bed and the bubble capacity of a million tons of soap are crude and inadequate figures of comparison. We must remember that in extra-mathematical investigation we judge everything by human standards, but that in reality anything which can be expressed as a mathematical formula is as simple in nature and in operation as the facts of every-day life. If we do not get away from the habit of setting limits to every conception—limits based upon our own surroundings—we shall find our speculations conflicting with science at every turn.

The knowledge of principles clears the fog in which the speculative mind wanders in search of resting spaces, and the secret of clear conception lies in the ability of ridding oneself of *pre*-conceptions. If in attempting to conceive the speed of propagation of light we bring to mind the speed of a railway train or of a rifle bullet, we set a limit to our mental grasp, just as a student who can not assimilate an algebraical formula without an arithmetical parallel shuts himself out of the higher mathematics.

The greatest limitation from which our forefathers suffered was the rushing to conclusions from analogies, and the shallowness of the results can not be better illustrated than by quoting from a book called "The Art of Metals," published in the year 1640, and at one time considered an authority in matters metallurgical. Referring to blue copperas, or sulphate of copper, the learned author writes:

> It is admirable to see its effect in *Aqua-Fortis*, (in which all Mettals like Salt dissolve and are turned into water) and an occular demonstration of the possibility of the transmutations of Mettals one into another, for with Copperas dissolved in *Aqua-Fortis*, (without any other artifice) Iron, Lead and Tin become fine Copper, and Silver will lose of its value, and be turned into Copper also.

When discussing the principles of physical science we are confronted by a condition which continually vitiates clearness of exposition. Conceptions of energy and of matter are now becoming more and more convergent and we find ourselves in the dilemma of having at times to think of matter as energy and at the same time to describe energy in material terms. The world of science is becoming daily more accustomed to the convertibility of the terms energy and matter; but there is a natural tendency to incredulity, for, as some one recently stated:

> In the estimation of material beings matter must necessarily assume a position of special importance; but nature may not perhaps regard it otherwise than as one of numerous forms of force, between which (as Newton wrote) it "delights in effecting transmutations."

We shall return to this subject later.

There exists a public impression that the dreams of the old alche-

mists who, with the possible exception of an occasional Paracelsus, sought hap-hazard for the transmutation of the metals, has been vindicated by the disintegration theory of atoms and the discussion of the possible transmutation of one chemical element into another. This is doing altogether too much honor to the alchemists whose only object was personal enrichment; there is no credit due to them; the most extravagant theory may be realized under suitable conditions and in this mysterious universe any condition or concurrence of conditions seems to be possible.

Theories of Matter

For the belief that all matter may have a common origin, we must go back twenty-five centuries to Thales of Miletus and the hylozoistic school; it is another case of the premature leakage of subliminal wisdom. Sir Norman Lockyer can be said to have put the theory into tangible form by his work on stellar evolution which has developed the fact that the complexity of stellar matter is a function of its temperature. The higher the temperature of a star is, the fewer and the simpler are the elements present. Würtz wrote that "the diversity of matter results from primordial differences, perpetually existing in the very essence of these atoms and in the qualities which are the manifestation of them." Ascribing a common origin to all matter would tend to make the formation of new compounds from heterogeneous chemical elements appear more rational.

The problem of the ultimate structure of matter has stirred the philosophers of all ages, Democritus and Leucippus were the real discoverers of the atomic theory, and Lucretius was its poet; but the times were not propitious for its use as a working hypothesis; it was not, therefore, until revived by Gassendi and adopted by Dalton, that it became acceptable to science. As long as the chemist was obliged to work with *molar* masses of matter, his work was unsystematic and in a great measure fruitless; the atomic theory put things in their place and gave the chemist definite *molecular* masses with which to work. The proof of the atom has been its results; we have not here a question of nature, nor a question of form to discuss; the atom is a *fact* in chemistry, even if it has no existence in any conceivable form. Molar masses are continuous aggregates of molecules; molecules are definite aggregates of atoms. The selective qualities of atoms, the phase-rule, etc., belong at present more to chemistry than to physics, and they will, therefore, be left out of the discussion. Molar activity is known by its comparatively slow mechanical effects; atomic and molecular activity are known as heat and other forces, and as we go down the scale of size we find the activity more intense. But if it is unnecessary for the purpose of this exposition to discuss atoms and atomic aggregates, it is very important to understand the rôle of ions.

Positive and Negative Ions

An ion is a charged atom, an atom carrying a quantity of electricity, such, for instance, the dissociated atoms of an electrolyte. Ions can be compared to diminutive Leyden jars, and as it has been discovered that they all carry the same charge and that each atom has the same electrical capacity, the physicist has been enabled to count the actual number of ions in any gas by the electrical properties of the gas. If an ion is electro-positive, it is known as a cation; if electro-negative, as an anion —two old words due to Faraday, which are immediately related to the familiar terms of cathode and anode.

Whatever the essential difference between them may be, the two electrical states (+ and —) may be said to differ chirally only, or, to give a more distinct if rather crude mechanical analogy, one may imagine that two discs, each suspended by a thread in its center, are revolving at a high uniform speed; if they revolve in the same direction they will spring apart as soon as they come into contact, part of their motion of rotation being converted into motion of translation; if they revolve in opposite directions their motions will not interfere, in other words they will be "in mesh." Thus, according to this conception, each is the enantiomorph, or opposite form, of the other; positive and negative charges of ions are equal but opposite. This idea of opposite charges owing their difference to opposite directions of rotation is only a working hypothesis, but is worth keeping in mind.

Distinction between Energy and Force

Having adopted negative and positive ions as the basis of matter, we must now examine the distinction between force and energy before going any further into the sub-atomic world. Force is the action, the manifestation of energy, just as visibility is a physiological manifestation of light. Light, in the abstract, is energy; in the concrete, as something that we see, it is a force. It is propagated as energy and manifested as a force; force, therefore, always implies matter.

As we shall have opportunities to see later, all energies are almost certainly modes of motion. Matter, on the other hand, is perhaps best described as whatever can occupy space, but this description is not suited to all theories. If motion is an essential property of matter, matter might be best described as whatever possesses energy in virtue of its motion; but in this essay the nature of matter will be discussed, and not its structure.

The ether, in which energy is manifested, may be said to have owed its recognition to the impossibility of believing in action at a distance and through a void space. Sir William Crookes at one time suggested a fourth state of matter for the ether; before accepting this theory, however appropriate it may appear, it seems reasonable that all the

possibilities within range of our understanding be exhausted; we can hardly expect to understand a fourth state until we have fathomed the relations between the three states which we already know, and also their intermediate forms which immediately precede their critical points of transformation. We may some day be forced to an acknowledgment of this fourth state, although we may never be able to conceive it. It would be somewhat surprising that the ether be in any form known as matter; much more surprising than that matter be, after all, but another manifestation of energy.

It is a common thing for writers to dwell upon extinct theories. History is very well in its place, but in this essay extinct and not-generally-accepted theories will be disregarded in favor of those of more recent growth, or such as may be suggested by the recent discoveries in physical science. On this account it will be necessary, in the first place, to review very briefly the present state of radiology, without a knowledge of which a proper understanding of modern theories would be difficult.

The Facts of Radiology

Credit must be given to the early work of Sir William Crookes on radiant matter for having prepared the way to recent discoveries in this branch of physical chemistry. Credit must also be given to Sir J. J. Thompson, for work on the electric properties of gases, without which many of the important facts of radiology would have remained either undiscovered or barren, to which have been added his many masterly discoveries in the electronic world.

The most studied radio-elements and the most interesting for the present discussion are uranium, actinium, radium and thorium. The distinctive property of the radio-elements is to disintegrate, forming other radio-elements and also a more stable element. The disintegration is not molecular; it is atomic; the atom breaks down, it is destroyed or converted into the atom of another element. Radium is apparently de-energized uranium; the spectrum of uranium is entirely distinct from that of radium and they may therefore be considered distinct chemical elements. The radiations and emanations of all radio-elements being, in a general way, the same, it is only necessary to describe in detail the disintegration of radium, which is the most interesting and complete of all.

The magnet will separate the radiation from radium into three distinct streams, just as a prism will break up white light into its physiological primaries. These three radiations are known, respectively, as α, β and γ radiations, and radiations possessing similar characteristics are given off by all known radio-elements. The α radiation, which appears to be composed of helium atoms, has secondary rays composed

of particles, until recently considered negative electrons, but, according to Professor Soddy, by no means finally proved as such for all cases. These particles of the α radiation are probably of relatively large size and are beautifully exhibited by the scintillation of the zinc sulphide in the spinthariscope. The β rays are extremely complex and interesting and their power of penetration is about ten times that of the α rays. The γ rays, which are themselves about ten times more penetrating than the β rays, but do not affect the photographic plate to an equal extent, seem to be produced by the explosive disturbance which takes place at the formation of the β rays, just as X rays are produced by the impact of cathodic rays; in fact, these γ rays are very similar in degree of penetration and in some other properties to the X rays. In addition to the γ rays, the explosive disturbance referred to produces an emanation, a veritable spray of the radio-active element. The emanation is, according to present standards, a form of matter, whereas the radiations can not be positively defined as such if judged by the same standards. The emanation, which is therefore a spray of the radio-element, a vapor, renders any object bathed in it radio-active and the action does not cease until the dust deposited on it has decomposed into radiation and emanation. The most significant product of the disintegration of the radio-elements, however, is helium, which has been mentioned in connection with the α ray; it is a distinct element with a distinct spectrum, perfectly stable chemically and therefore quite unlike the other products of disintegration.

Helium seems to be the state in which the unstable atom of the original uranium at last finds rest. It has been suggested that the helium may be merely occluded, but valid arguments have been brought to bear against the idea, and, if anything, radium would be a true compound of helium and of some other element. It has even been suggested that all chemical elements may be helium compounds. This is a return to Prout's theory, but with helium in place of hydrogen. Contrary to general belief, helium is not exclusively a product of the radio-elements; Strutt has recently succeeded in obtaining a very fair percentage of it from New Hampshire beryl which did not exhibit any measurable radio-activity; it may, however, have done so in the past, the helium remaining occluded.

The speed of decomposition of the radio-elements, or rather of their salts—the bromides and chlorides being the most generally used—is so rapid that the use of chemical methods of analysis is almost hopeless. Radium is comparatively manageable, but actinium, which is said to be at least one thousand million times as active as radium, has a life period of less than eight seconds. It has been suggested that actinium is an intermediate product between uranium and radium.

The Disintegration of Matter

One of the latest developments of the theory of the disintegration of matter is a suspicion, which scientists hardly dare to voice, that there is a continual disintegration of *all* matter, stability being only relative and the new and perfectly inactive gases discovered in the atmosphere being among the most stable elements. It is just as natural for the atom to die as for it to be born; if we accept the latter, we can not deny the former. The atom of matter slowly expends its energy as does a watch-spring in doing the work of keeping time. Matter, according to this theory, is concentrated energy, the dissipation of which is almost too slow for us to detect. This theory has been taken advantage of to try to explain the sun's effulgent shell, and the question arises: when the unstable matter of the sun has completely disintegrated, will it become a globe like ours, dark and relatively cold, a mass of molten iron in the complex slag of which creatures not unlike ourselves shall dwell and dig for mineral treasures, subject to the changed conditions? Has our planet itself been through that state? Such a supposition is certainly no more extravagant than many we have heard, and the scarcity on the earth of radio-active substances and of the rare-earth elements which are such powerful emitters of the more useful light waves, does, in some measure, support such a theory.

However, in order to show the immense periods of time which are brought into question, we might borrow the following impressive example: one cubic centimeter of hydrogen contains approximately 525 octillions of atoms; if 10,000 of these were allowed to escape every second it would take about 17 quintillion (17,000,000,000,000,000,000) years to empty it. Upon a similar basis of expenditure of their contained energy by atoms of matter, it is evident that the detection of this expenditure would be very difficult. Before returning to the ether the electric atom or electron must be studied.

Corpuscles and Electrons

To understand what an electron is, we must imagine an ultimate particle—not a particle of matter, nor a particle of force, but just simply "a particle"—and let us give to this particle the old-time attribute of the atom; let us assume it to be indivisible. This, of course, is only a working hypothesis. This particle considered in the abstract we shall call a corpuscle. If we endow it with energy we shall call it an electron. Quite possibly the corpuscle can not exist except as an electron, or atom of negative electricity. However this may be, we must assume, in order to facilitate the discussion, that a corpuscle is only an electron when it is endowed with sufficient motion, which may be either vibrational or translatory, to manifest itself to us electrically. We shall assume that the abstract corpuscle exists, and that it only becomes an

electron when it is energized. Atomic action and the behavior of charged, or rather unbalanced, atoms, called ions, belong as much to chemistry as to physics, but corpuscular motion is purely physical as yet; it has no direct bearing that we know of on chemical reactions. As regards the nature and dimensions of corpuscles, J. J. Thomson has estimated them at one one-thousandth the mass of the hydrogen atom. As regards speed of translation, many radiations composed of electrons approximate the speed of light; this represents almost nineteen million times more activity than the one mile per minute ascribed by Clausius to the hydrogen atom which has already been taken as a standard of comparison. There are some very interesting theories to be derived from the study of electrons.

The Atom and its Metamorphoses

The present theory of the atom as derived from radiology is that it is composed of electrons moving rapidly in all directions and necessarily in constant collision; these electrons are assumed to be held together in each individual atom by a positive force. Differences in the number of electrons in an atom give rise to different elements. Imagine a glass globe of about the same diameter as the dome of St. Peter's, in Rome, with a quantity of grains of wheat shooting about inside in all directions, and acting and reacting by continual collision; the globe itself represents the force which keeps the electrons within the compass of the atom; the grains of wheat represent the electrons. We can, if we wish, assume that the electrons have orbital motions in relation to one another, as regular as those of the planets; it is only a difference in mass and in speed, and the mass being so enormously smaller, it is not surprising that the speed be so enormously higher, and, furthermore, there is no reason for thinking that the same laws which regulate a solar system may not regulate an atomic system. When the atom disintegrates it loses some of its electrons until a balanced system is reached, and it can then be assumed to be a stable atom, of a different element, however, provided the loss of electrons was not complete. If the theory of universal, or almost universal, disintegration and re-formation of atoms is correct, there is a constant outpouring of electrons from all atoms of matter, which even with a liberal allowance of units per second would hardly amount to an appreciable difference in atomic characteristics within historical periods of time, but which, premising a common era of formation for terrestrial elements, might explain the fractional discrepancies in atomic ratios; if such a theory were true, the elements as found in other worlds might have slightly different chemical constants.

As recently suggested by the author,[1] if the atom is continually

[1] *Nature*, February 18, 1909, p. 459.

losing electrons and, therefore, atomic weight, until, a certain critical point being reached, a readjustment takes place resulting in transmutation to a lower element, it may be supposed that the atomic weights of the elements may vary in different worlds of space. The more or less uniform weights found on this planet would be due to the fact that the period of formation was practically identical in all cases. The slight divergences between the theoretical and actual atomic weights in the periodic system would be due to the electron contents having fallen below the contents at the last points of readjustment. The list of the chemical elements arranged in decreasing order of their atomic weights would represent the steps of the degradation from the highest elements having, possibly, atomic weights exceeding 250. It was further suggested that the atomic weights of the elements in meteorites be determined to check the truth of the theory of transmutation by disintegration; as far as known this has not yet been attempted.

It would seem to be rather idle to discuss the possible reasons for the diversity of elements in each chemical group on the assumption that they all originated at one time for each individual body in space from extremely dense elements, themselves concentrates of the one primal element. At most, it is proper to state the theory as follows. As the nucleus of a nebula condenses and cools into a solid mass, the structure of the matter at the center becomes extremely dense and the atomic weights are high; these weights taper off to the surface, which is then of a somewhat irregular and slag-like nature like the crust of the earth and brings to mind many parallel cases in metallurgy. Many scientists hold that the earth has solidified more or less in the shape of a modified tetrahedron; if this be true, it encourages the view of a fairly homogeneous core which may be composed of elements even heavier than radium, thorium and uranium. The radioactive properties of these elements may account for the internal heat of the earth. The view that the bulk of this globe of ours is of similar composition to the crust is not only unjustifiable, but highly improbable; the slag of a steel-making process is a good indication of what there is *not* underneath. The theory of a core composed of elements having high atomic weights will go far to explain the high average density of the earth as compared with that of the crust.

The Electrical Nature of Gravitation

A discovery of inestimable value is due to Kaufmann; he found that the *mass* of the α particle *varied with the velocity*. This discovery all but consecrated the old theory that mass, that gravitation, is a form of energy, a mode of motion. There can not be a *manifestation* of energy when the motion is uniform. No motion of energy can be evidenced without acceleration followed by arrest and a reversal of motion, or

what is known as "periodic acceleration," pulsation or vibration. We can not measure a uniform motion in a particle moving with the speed of light, but we can measure its acceleration. All forces pulsate; they are all propagated as waves, which set up vibratory motions in matter and thus make their presence evident.

In support of this statement about the nature of mass, which is of such fundamental importance, the words of Professor Rutherford may be quoted:

> **If a charge of electricity in motion exactly simulates the properties of mechanical mass, it is possible that the mass of matter in general may be electrical in origin and may result from the movement of the electrons constituting the molecules of matter.**

It is to be noticed that Professor Rutherford refers to the electrons as charges of electricity. His words give a full, if concise, definition of the electrical theory of matter which is accepted by the mass of physicists and of which Sir Oliver Lodge is the able historian. When Davy suggested that matter and electricity were kindred phenomena he could hardly have suspected how near he was to the truth as it is seen to-day. The materialists and energists are now on the high-road to reconciliation, and we are permitted to feel that an explanation may soon be forthcoming for the well-known relation between specific heat and atomic weight, and for that existing between spectral phenomena and atomic weight.

The matter of gravitation can not be put aside without a few additional remarks. Lord Kelvin, by calculation, has ascribed to the ether a weight of one-thousand-billionth of a gram per cubic meter. This is not very much, and can give little encouragement to Lothar Meyer's suggestion that the slight divergences between theoretical and actual atomic weights in the periodic system may be due to the imprisonment of a quantity of the ether within matter; as just suggested, these differences are more likely due to electronic losses.

If the new theory of mass is accepted we must postulate a quantity of energy in the ether in keeping with its weight. We shall know more about this when these quantities have been calculated by different indirect methods and the results compared. We shall have occasion, a little later, to discuss the temperature of space between which and its internal energy and mass some relation may exist. Heat is usually considered to be due to atomic agitation; we are now assuming mass to be due, possibly, to corpuscular agitation, which already produces, as we know, light and other electro-magnetic phenomena. The day may come when, able to control the internal forces of the atom and effect transmutations, man may set about destroying matter, as such, altogether, for use in his industries at so much per kilowatt-hour. To the peculiar forms of insanity which induce some men to sell eternal salvation and others

to capitalize the future, will be added the new feature of utilitarianism of annihilating the earth in order to improve it as a place of habitation.

Chemical Theory of the Ether

Returning to the ether, we find ourselves in better position to discuss its probable nature, and the first theory to be examined, while perhaps the least satisfactory, merits respectful consideration as coming from such an authority as the late Professor Mendeleef, who gave its full development to the periodic system of Newlands, with its strong argument for a common origin of all the chemical elements. Mendeleef's theory is known as the chemical theory of the ether. He suggests that space is filled with chemically inert gases such as argon, krypton, neon and xenon; thus, no chemical reactions would be possible in space, although it is filled with what is actually matter. This is a return to the Cartesian theory of matter filling all space, and implies an atomic structure of the ether. From a purely structural point of view, Mendeleef's theory is not incompatible with the theory of an ether entirely made up of corpuscles, but on account of the larger size of atoms it would be more definitely granular, and therefore less continuous. Cauchy has attempted to calculate the probable dimensions of ether particles and claimed one ten-thousandth of a wave-length as a result. This is not an encouraging figure for the chemical theory, as it is very much smaller than any of the atoms known to us, and it is worth while on that account to examine some of the physical conditions of the medium in space.

This medium is, according to the figures of reliable investigators, under considerable pressure, and Professor Poynting tells us that interstellar space is at a temperature of about 10° abs., or several degrees warmer than the lowest which Sir James Dewar has been able to obtain by artificial means. This would be, of course, an average temperature, because variations must exist in different parts of space. The high pressure combined with low temperature is not in itself suggestive of the presence of known gases.

There is no indication that a fall of temperature lessens chemical activity—in certain cases it has been found to increase it—nor that it in any way accelerates the disintegration of atoms, and there is no reason, therefore, to believe that gaseous activity would be reduced in space by the absolute, or almost absolute, withdrawal of heat. This statement may appear to contradict a previous statement that heat was the result of molecular agitation, but it does not, for gaseous activity, which causes expansion, is an intrinsic activity entirely independent of, though influenced in degree by, the superadded activity imparted to masses or aggregates of gaseous atoms or molecules by heat waves passing through them. Furthermore, no extrapolation of results actu-

ally obtained warrants us in suspecting that molecular aggregates can not exist at zero absolute; thus we may well believe that chemical affinity, while influenced by temperature, is in no way dependent on it, but is an intrinsic property of the atoms themselves. Gaseous matter in space is not necessarily "frozen to death."

It has just been stated that there was no indication that a fall in temperature hastened atomic disintegration; the reverse may be true. Jean Becquerel has recently shown that at the temperature of liquid air the transparency of matter increases and the spectral absorption bands become finer. It is well known that the very opposite is the case with a rise in temperature above normal. In this we may see a vindication of the theory that heat is due to molecular agitation, or, to speak more correctly, is manifested as molecular agitation, which interferes with translucent properties.

Phenomena of Interstellar Space

If the ether is a mass of elementary gas or gases, in what relation will it stand to the energies which it transmits? If the ether is gaseous, *i. e.*, material, all our accumulated knowledge of matter is at variance with the accepted facts of astrophysics. If this gaseous ether is the ultimate condition of matter, the luminiferous medium, all our accumulated knowledge of the ether is opposed to many accepted facts of science. The acceptance of a material ether necessitates too much work of reconciliation and the distortion of established facts to suit its requirements. We turn, therefore, to sub-material theories.

The ether transmits but does not manifest heat, light and other forms of energy. Light is not manifested in space—at least not to any appreciable extent; the variations in our distance from the sun do not produce color phenomena of the order of those which a variation in the depth of atmosphere through which we view the sun produces. Heat stands in the same relation to the ether as sound does to gases of suitable density; it is not *manifested* in a non-material ether; it is *transmitted,* and that part of space through which it passes is unaffected. If a molecular mass, our globe and its atmosphere, for instance, be interposed, the light and heat will be manifested, dissipated and finally absorbed by atoms or atomic aggregates, the periods of whose vibrations coincide with theirs. If not manifested they can not be dissipated, but will travel forever in a right line.

But if this is correct, how is it that interstellar space possesses any temperature at all? Why is it not at zero absolute? Heat, as already stated, is known to us by its manifestation; it is manifested in matter and ultimate corpuscles can only transmit it without retaining it. Heat and light may be identical in nature, but they are distinct in their action; it has recently been shown that the change of period in the

movement of electrons which absorb light is quite independent of temperature, thus confirming the theory that heat does not affect the corpuscle as it does the atom, and that therefore space, if it were corpuscular (sub-atomic) in composition, could not possess temperature.

Assuming that Poynting's calculation of the temperature of space is right, or even adopting that of 1.5° Centigrade absolute, as was more recently calculated by Schaeberle, we shall either have to accept a material theory of the ether, like Mendeleef's, or else suppose that molecular dusts—solid, liquid or more likely gaseous—are present in space, as material impurities in a sub-material medium. Such a supposition, recently made by the author,[2] is not only possible, but is highly probable. If, as is far from unlikely, this dust is found here and there in masses more dense through which our planet glides, we do not have any further to seek for another explanation of the *aurora borealis* and kindred phenomena, which would be caused by the electrification of this dust when near the earth. These auroras occur at irregular times, whereas the theory of Arrhenius, which attributes them to cathodic rays emanating from the sun, would lead us to expect a continuous or periodic performance. By adopting Villard's theory of the telluric origin of the cathodic radiations of the phenomenon, we can introduce the cosmic dust as a rarefied gas in which it is displayed. Zodiacal light will be due to dusts burning when contacting with our atmosphere, just as on a large scale and detachedly, meteorites will illuminate the sky. Night brightness, as for instance the "extraordinary lightness of whole nights in the year 1831, during which small print might be read in the latitude of Italy and the north of Germany," mentioned by von Humboldt, might have been due to a very dusty condition of space following solar activity. Abney has claimed that the region of space which we are traversing contains benzene vapor, ethyl hydride and other alcohol derivatives; these would assuredly burn when in frictional contact with the atmosphere. The more recent suggestion of a permanent corona around the earth which becomes visible under certain conditions as sky lightning does not stand analysis, but such a corona will exist as the earth passes through dusty regions in space.

If the sun, out of those vast cavities in the photosphere which are called sun-spots, belches forth this cosmic dust, undoubtedly gaseous in at least its early constitution, and the earth gravitates through it, the electro-meteorological disturbances which are observed one week or so after the appearance of spots would be, in a general way, fairly well accounted for. It is significant that the growth of the red flames which has been estimated about 200 miles a second corresponds to a period of about six days to bridge the distance between the sun and the earth's orbit. It is to be expected that this planet be influenced by a material

[2] *Science*, Nov. 20, 1908, p. 728.

bridge between it and the sun. Sun-spots are regarded by many astronomers as a falling-in of a portion of the photosphere, but the reasons for this belief are not conclusive, and it is legitimate to believe in a movement in the opposite direction due to an explosive force within the effulgent crust which, as in the case of volcanoes, occasionally relieves the tension beneath that crust or in its cavities. Our periods of greatest heat often follow sun-spot activity—not that sun-spots are hotter than the rest of the sun's surface, but the matter which is sent forth intercepts and stores heat before it can pass beyond the limits of our orbit to be absorbed by extraneous systems.

A last consideration which makes the chemical theory of the ether untenable is the fact that if space were filled with gases, the temperature near heated bodies like the sun would be very great, and powerful currents would be set up which would be detected by optical if not by other means. A material ether would possess some degree of viscosity and would necessarily interfere with the progress of bodies, and this negative acceleration would create heat of friction, dissipated but undestroyed. This leads us to the consideration of the physical requisites of an ether in which matter, as we know it, must "fit," before we examine any of the other theories which have been offered within recent years.

Failure of Material Conceptions of the Ether

All the experience which has been acquired through telescope, microscope and spectroscope, with and without the aid of the camera, leads to the belief that the all-pervading medium must be uniform and homogeneous. While this may be taken for granted, it by no means implies that the medium must be continuous; in other words, each of its components does not necessarily have to stand in any physical relation to its neighbors, for this would imply a force of affinity or of cohesion which one may be unwilling to grant, as it yields a purely material conception and carries one back to the chemical theory, which has been laid to one side for the present.

Some of the most eminent physicists have adopted the view that the universal medium must be solid; this belief is based on the manner of propagation of light and other high-frequency energies, which take place without appreciable dispersion in space. But, on the other hand, in all theories but one, this medium is expected to be of a nature which will offer little or no resistance to bodies moving through it. At first sight it is hard to reconcile this requirement with the nature of a perfect elastic solid such as we picture to ourselves. It has been suggested that the medium must be somewhat like pitch which shows no track of a body which has passed through it, and we are asked to conceive our planet—not to mention our humble selves—moving at a rate of eighteen miles per second through it, and, what is still more incredible,

that this takes place without practically any friction. The truth of the matter is that whether we call it a perfect gas, an incompressible fluid, a jelly, or a solid possessing perfect elasticity, we are tying ourselves down to a material ether, and the acceptance of any one of these conceptions ends in a *reductio ad absurdum*.

As for dispersion, if it be assumed that light is given forth from the entire surface of the sun equally in all directions, the lateral pressure of dispersion at each spherical zone, and at any distance—if it exists—would be equal, and there would be perfect equilibrium between adjacent cones of light; the bases of these cones are equipotential surfaces and no lateral dispersion could be rationally admitted. When, however, the light waves strike an object such as the earth, a shadow is formed. Leaving out the refraction in our mantling atmosphere to which we owe our twilights, the shadow which the earth casts is practically absolute for at least the distance from the earth to the moon (240,000 miles); and it is therefore evident that the medium itself is of such a nature that it will transmit transversal vibrations without any appreciable dispersion. If dispersion in space were serious the light of the stars would be shown as a haze and not as individual points,

The theory of a solid or, to speak more accurately, a rigid ether does not, as we shall see later, appear to be a necessity, and it presents the great weakness of compelling us to rack our common-sense to try and explain the passage of bodies through it, from the lightest comet to the most massive star. Rigidity of rotation was first proposed by McCullagh and its nature will be considered more fully when the subject of vortex-atoms is reached, but, however plausible it may be for material atoms—and it is eminently so—it seems to be a superfluous hypothesis for a non-atomic ether. Rigidity and elasticity of rotation can be compared to the gyroscope which resists deflection and yields elastically, although it is not itself elastic, nor immersed in a medium which could be considered elastic when the gyroscope is at rest. This is an elasticity of motion, not of matter; it must, however, be remembered that, as Lord Kelvin has pointed out, elasticity itself may be but another mode of motion. With elasticity of rotation, one might have practically a fluid ether possessing high elasticity with its oscillatory power, instead of the viscosity of ordinary fluids, with its dispersive quality.

Perfect elasticity by no means implies a solid or semi-solid state; an atomic structure presents elasticity of volume, but equilibrium in a homogeneous, non-continuous medium, regardless of the spaces which may exist between the component incompressible corpuscles, will supply rigidity and elasticity of shape. Pressure in space does not imply elasticity. If elasticity is a rotational effect and pressure one of bombardment, they are not necessarily interdependent. The fact that there

may be pressure in space brings one back to the consideration of a gaseous ether, but can not pressure exist in a corpuscular medium, and may not the pressure be a manifestation of the innumerable energies which continually pulsate through space? If all forces—including chemical forces—were suddenly removed from a certain point in space, there could be no activity and therefore no pressure. Pressure is the result of activity, of bombardment, and space is truly "alive" with activity, for, as Clerk Maxwell said, energy transmitted must exist for a time in the medium. No wonder, therefore, that it is under pressure, which Sir Oliver Lodge estimates as equivalent to 10^{37} ergs per cubic centimeter.

Before leaving the subject of pressure in space, it may be well to look further into the matter of ethereal activity. The activity of the ether might very well be of a higher order than that of the energies or forces known to us. When we consider that as far as we can discover the hottest stars have the simplest spectra, it may well be suggested that gravitation, electricity and light may represent falls of potential and not rises from the inherent activity of the ether, which, calculated to secure the necessary rigidity in the theory of vortical motion, is of stupendous magnitude. This degradation of the energy of the universe of ether into the energies known to us is in the same line of development as the degradation of matter, and the laws regulating the conceivable may logically govern the inconceivable.

No *material* conception of the ether is therefore to be considered excepting one which, at first sight, appears perfectly paradoxical, of an elastic solid of a density of 10^{12} (Lodge), as rigid perhaps as steel, and, in that case, fifty thousand times less dense than hydrogen (Michelson).

The Creation of Atoms

If, as already stated, energy, as we know it, is originated in matter—though not by it—and transmitted through a medium the ultimate particles of which are very much smaller than and different in nature from the atoms of matter, the disturbance at the source of origin must be transmitted by a number of corpuscles of that medium and propagated as a bundle of vibrations several corpuscles in diameter. This bundle of lines of force may be called a tube of force; this tube of force may be of any shape whatsoever, depending on the shape of the source of origin and the nature of its disturbance.

Plateau has shown that a liquid cylinder of excessive length and *with a free surface* first assumes an undulating contour, and then breaks up into separate vibrating drops. The resistance of the medium apparently puts the stream into vibration which causes a separation into equal drops by periodic strains which finally overcome the surface tension. The researches of Bjerknes confirmed Plateau's experiment

and he found that the distance required for the breaking into drops depended, as might be expected, on the relative densities of the liquid and of the medium. Savart had shown that this natural tendency of liquid columns to break into drops can be induced by a musical note which synchronizes with the period of the drops.

We can now build what is possibly a wild theory, by means of that dangerous tool of philosophy: analogy. Let us imagine a bundle of energy not having a free surface but forming part of a general spherical disturbance, striking an object having an aperture which does not absorb or reflect the energy and therefore acts as a diaphragm; suppose that a cylindrical pencil is thus formed and propagated beyond the obstacle; this tube of force will have free surfaces; the analogy with the behavior of liquids dictates that after a while the tube will resolve itself into spherical drops and these drops we shall call atoms. We have thus created atoms from corpuscles and the energy traversing them; we have given an origin to what Crookes has called an "atomic fog," which is, according to the nebular hypothesis, the basis of the material universe. The "atomizing" of a liquid and the shredding of lead (lead-wool) by an air blast are identical in principle.

But the hypothetical diaphragm can be used to produce quite a different atom from the spherical drops which have just been created, provided the vibration be brought about *before* the energy, corpuscles, electrons, or whatever we wish to consider them, are ejected beyond the diaphragm. If a box with a hole (diaphragm) in it is filled with smoke and the side opposite to the hole is given a short tap causing the smoke to vibrate, a ring of smoke, a vortex ring, will be emitted, with the appearance and general properties of which we are well acquainted. A continuous motion of the smoke will not produce a ring; it will produce a stream, with a skin resistance like the stream of smoke in a chimney; to produce a vortex ring, a pulsation is required which will emit small disks of smoke which can be thinned at the center to the point of rupture by the resistance on the edges of the hole. If, therefore, a tube of force pulsates or is caused to pulsate by an elastic or pulsating resistance or otherwise, when it strikes the diaphragm in the obstacle, a vortex atom will be produced in place of a spherical atom. We have thus created the vortex atom as first proposed by Helmholtz and developed by Lord Kelvin into a theory which has stood the most careful mathematical scrutiny.

That an obstacle in the path of a stream of energy will alter that energy is evident. The conversion of cathodic rays into X-rays shows what impact may do. The clash of two similar or dissimilar streams of energy might create spherical or vortical atoms and the relative speeds and the angle of impact would influence their period of vibration.

The radiation from disintegrating matter on this planet may go far

out into space to re-create atoms for use in some other system. The sun, while emitting an enormous amount of energy, may be gathering an equal amount and be a vast atom-factory. Vico with his "metaphysical points" and Boscovich with his theory of centers of force for atoms were the forerunners of the theory that matter is energy objectified, a theory so startling that it would be unwise, not to say positively indecent, for modern science to accept it offhand without at least a show of suspicion. Anaxagoras saw in the energy of atoms the evidences of mental power; even the most sceptic must refrain from criticizing or judging the statement that the energy of the atom is entitled to be called intelligent in the broad sense. It is quite significant that protoplasm molecules are very rich in atoms, each molecule of human hœmoglobin containing not less than 1897.

The Vortex Atom

But we must now return to the vortex atom. It is a gratuitous supposition, all too widely accepted, that atoms must necessarily be round. Secchi favored a round revolving atom. Lord Kelvin and many others found that the vortex atom more completely satisfies the requirements of observed facts, but that the vortex atoms may vary in their shape and proportionate dimensions. It may be best to give Professor Tait's definition of Kelvin's vortex atom, instead of attempting to fashion a new one. "The rotating part of an inert perfect fluid, whose motion is absolutely *continuous,* which fills all space, but which is, when not rotating, absolutely unperceived by our senses." By "perfect fluid" is meant one which is frictionless, clearly an impossibility for matter in the liquid state.

The most pronounced features of the vortex atom as compared with other conceptions which have been offered are its elasticity and its permanent character; its mathematical study is of unusual difficulty, but the properties which it must necessarily possess coincide in a remarkable degree with the observed properties of atoms. The vortex ring, one made of smoke, for instance, can not be cut; it will move away from the edge of the knife; it can, however, be deformed and will vibrate in various ways. It can revolve axially or in any other direction. It is even conceivable that vortex atoms be linked so that a great variety of arrangements would be possible, corresponding to stereochemical groupings.

One more point must be touched upon. Is the ether stagnant or in motion? At first it may appear as rather a waste of energy to attempt to discover if the ether is in motion, but Professor Larmor has shown mathematically that the absence of any optical influence of the earth's motion on light from the sun and stars suggests that the ether moves along with the earth. From another source comes the idea that the

earth, being a magnet, drags the ether with it. In what a complicated turmoil the universe of ether would have to be if this conclusion were applied to all bodies in space! This dilemma brings us to the one theory which seems to clear up the most stirring mysteries of astrophysical science.

Reynolds's Theory of the Universe

The theory of the universe, which may perhaps be called the "dark horse," is due to the late Professor Osborne Reynolds, a thinker and mathematican of no mean caliber. The theory is thoroughly discussed and elaborated in his "Sub-mechanics of the Universe," which he very appropriately calls an "inversion of ideas." Instead of considering atoms as comparatively massive particles in a vacuum, a gas or a fluid, he considers them as *negative* inequalities or comparative vacua immersed in the perfectly rigid plenum which the phenomena of the universe require. The atoms in the ether might, therefore, be compared mentally to the pockets or bubbles of liquid in a colloidal emulsion. It is, of course, unthinkable that atoms be perfect vacua, that matter be the expression of nothingness; what is meant is that the ether is perfect fullness and that atoms are infinitesimal spheres of activity containing less ether; mass being a function of activity, there is no connection between quantity of ether and weight. It was with Reynolds's theory in mind that the statement was made that matter and the forces which make it known to our senses might possibly represent degradations of the inherent energy of the ether. The degradation of an element means at once loss of electrons and loss of mass; hence, perhaps increase of ether content or increase of *inactive* corpuscles, or even, which would amount to the same thing, loss of energy to corpuscles outside the atom. All this does not, however, solve the difficulty, it merely inverts the ratios of mass; to complete the system, a theory of the propagation or conduction of matter, in place of its transportation or convection, is necessary.

The Conduction of Matter

In the early days, astronomers found difficulty in ridding themselves of the geocentric idea, and in the same way it must be a difficult thing for the physicist to abandon the idea of positive matter; this conservatism is the fly-wheel of progress. Much harder still should it be to introduce the notion that matter is propagated like waves, like moving pictures on the cinematograph screen which truly live and give rise to emotions, although made up of nothing more tangible than lights and shadows. What a reversal of mental habits to conceive that the centers of force alone move and the component electrons change continually as the waves progress through the compact universe of ethereal corpuscles!

That such a propagation should take place without friction is possible, if friction is purely *intermolecular* and not an atomic operation like non-radiant heat. Heat, as already stated, is due to molecular agitation and all matter possessing heat above absolute zero is undergoing that particular form of molecular agitation; if the period of agitation is greatly increased by heating an article or greatly reduced by immersing it in liquid air, the effect on the hand at normal temperature will be much the same, physically, in either case; it is as if it were applied to a revolving emery wheel. The difference of period between the agitation of the molecules of the hand and that of the substance, whether positive or negative, will result in damage, the organic molecules being unable to respond without destructive decomposition to the periodicity with which they are put in contact.

If atoms can not vibrate in the order of heat or friction waves, any more than the optic nerve can vibrate in the order of sound waves, there can be no friction in the propagation of matter as postulated. Even if friction were interatomic, there would not necessarily be friction between atoms and sub-atoms. If there is any loss from the passage of atoms through space, it can not be as heat, unless the ether be atomic or molecular; it must be more in the nature of optical diffusion and the continual degradation of matter may be the effect of its propagation through space. Electrons may be strewn in the wake of each heavenly body to be swept up by comets in their courses and effect their growth, or gathered some day into nebular clouds from which new worlds will originate to take the place of those which wasted away in ages past.

The theory of the propagation or conduction of matter is equal mathematically to the ether moving with the earth. There is no actual relative displacement of the constituent corpuscles and it was therefore to be expected that, in the light of Reynolds's theory, Professor Michelson's elaborate experiment would fail to show aberration due to motion through the ether.

Man is a mass of prejudice; he is limited to one set of standards. From the first development of his organism from a zoophite, his senses have evolved in relation to matter alone, and it is only within recent times that he has commenced his evolution towards the understanding of submaterial truths. It may be untold ages before he may strike the endless path leading to the answer of the one and only problem in which he is interested and towards which he strives by the study of nature: the mystery of his self-consciousness.

The helplessness of the human mind in presence of the underlying facts of science is the deepest argument for a faith in some inconceivable universal mind of which our own is, at the very best, but an imperfect reflection.

THE VIENNA INSTITUTION FOR EXPERIMENTAL BIOLOGY[1]

By Professor CHARLES LINCOLN EDWARDS

COINCIDENT with the founding of our own government, the Emperor Joseph II., of Austria, opened to the public the Prater, the largest park in Vienna. At the entrance is the Prater-Stern, a street-car center directly accessible from all parts of the inner city and the outer districts by means of the city railway and many lines of electric cars. Here the people flock, especially on Sundays and holidays, to that part known as the Volks-Prater, which is a veritable Austrian Coney Island, with music, theaters, a giant wheel, circus, race-tracks, exhibits of natives from various lands and the attractive sights of "Venice in Vienna." On Easter Monday and May Day the largest and gayest throngs seek the Prater, where they visit the many forms of amusement, or walk and drive for miles through the park. Under the four rows of chestnut trees in the Haupt-allée the fashionable aristocrats parade in their fine equipages drawn by beautiful horses and bearing liveried coachmen and footmen.

The International Exhibition of 1873, located in the Prater, had an imposing aquarium constructed after plans by Brehm. More recently this structure has been used by the Zoological Society of Vienna as a vivarium for the display of the smaller animals. In consequence of the existence of an older zoological garden, the royal menagerie at Schönbrunn, it has not been possible to maintain this similar enterprise in Vienna. Following a suggestion of Professor Hatschek, Dr. Hans Przibram obtained the vivarium building from the zoological society in 1902 and joined with the botanists, Dr. Wilhelm Figdor and Leopold v. Portheim, in the establishment of an institution exclusively for scientific research which has already become renowned. The field is not limited, but offers an opportunity for the investigation of any biological problem, chiefly by means of experimentation, upon either plants or animals of the sea or the fresh waters, of the air, or the land, or dwelling in caves or burrows beneath the surface of the soil. The grounds, forming the garden around the vivarium building, were rented from the government for fifteen years. The main building (Fig. 1) had to be completely reconstructed and was then supplemented by two glass

[1] For his courtesy in lending me the photographs here reproduced and for his paper entitled "Die biologische Versuchsanstalt in Wien," *Zeitschrift f. biol. Technik u. Methodik*, 1910, I am especially indebted to Dr. Hans Przibram.

houses and various workshops and cages for the larger animals. The garden is screened from the passing throng by a vine-covered fence and a row of leafy shrubs and trees. As one enters the hall of the institution, he sees, on every hand, the preparations and specimens resulting from the experimental work so successfully carried on here. In the middle of the building are five parallel corridors, while to either side and in the rear are suites of rooms for manifold purposes.

The Vienna Institution for Experimental Biology includes zoological, botanical and physico-chemical sections. By virtue of an agree-

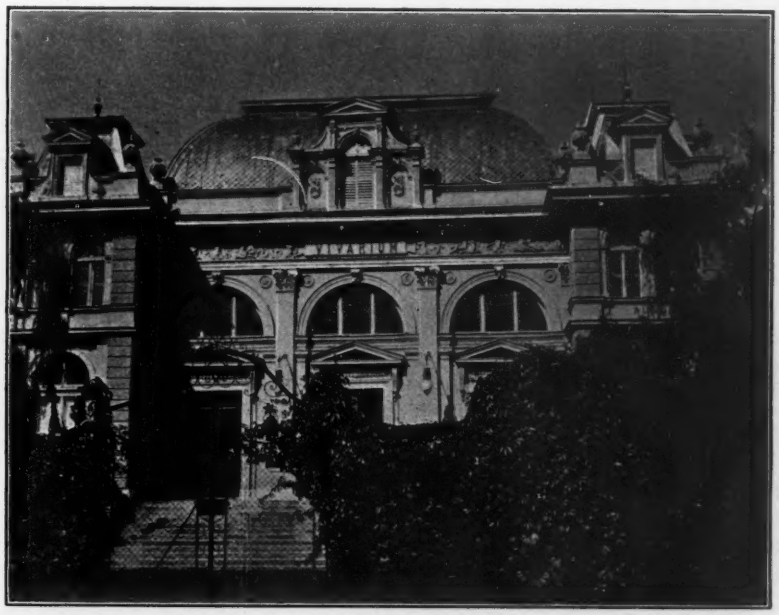


FIG. 1. FRONT VIEW OF THE VIENNA INSTITUTION FOR EXPERIMENTAL BIOLOGY.

ment with the royal Austrian ministry of education the state assists the founders by maintaining two laboratory places in each of the zoological and botanical sections. The award of these tables, as well as the promotion of the general interests of the institution and its close affiliation with the university institutes, is vested in a board of curators consisting of the four professors of the biological subjects in the philosophical faculty of the University of Vienna. Thus far these curators have been Professors Wiesner, in botany (chairman), Grobben and Hatschek, in investigation of the fresh waters of Austria, which thus far has been established for the physico-chemical section which was organized in 1907, and this place is filled by the professors of the medical faculty. The ministry of agriculture has made an annual appropriation for the zoology, and v. Wettstein, in botany. A governmental table has been used for botanical researches under the direction of Professor v. Wett-

stein. The tables are free to students working under the supervision of the directors, but independent investigators pay an annual fee of 1,000 crowns. About fifty workers are here engaged in investigations each

FIG. 2. TERRARIUM.

year. At present the staff of the institution is as follows: zoological section, director, Dr. Przibram, assistants, Drs. Kammerer and Megušar; botanical section, directors, Dr. Figdor and Ritter v. Port-

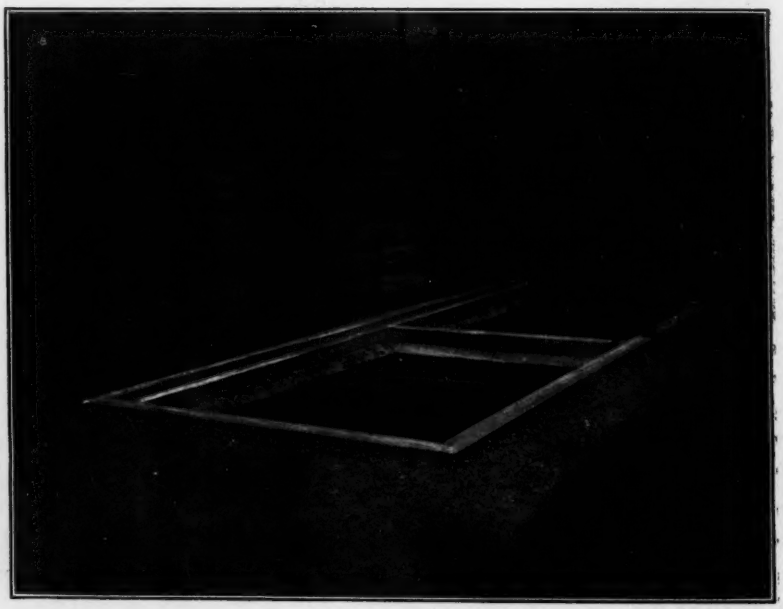


FIG. 3. OUTDOOR TERRARIA.

heim, assistants, Herr Fröschel and Herr Freund; physico-chemical section, director, Professor Pauli, assistant, Herr Schorr; fresh-water investigations, Herr Brunnthaler.

The Vienna institution differs from most of the preceding biological institutes in that here experimentation, carried on for long periods of time, even generation after generation, if necessary, and always under the best possible conditions, takes the place of research in descriptive and comparative anatomy, or the briefer experiments of physiology. In the study of experimental evolution one not only follows the organisms through ovulation, fertilization and embryogenesis, but the new generation must be raised to the adult stage for another breeding. The laws through which the external factors of existence influence the vitality can only be determined when it is possible for the organisms

FIG. 4. HOUSE FOR HIGHER VERTEBRATES.

experimented on to live under unchanging conditions for months or even years. Darwin acted upon these principles and his garden at Down must always rank as one of the greatest laboratories for experimental biology. It is only necessary to visit the zoological institute in Würzburg with its vivaria, series of basins and shaded pond, to realize, as one can from his writings, that Semper also was fully aware of the primary importance of experimentation in the solution of biological problems. Along with the foundation and growth of the Vienna institution has been that of the station for experimental evolution of the Carnegie Institution created and directed by Davenport, and the gardens developed by Ewart and Bateson in Great Britain. Similar establishments for the study of genetics have been advocated by Behla (1894), and more recently by Plate (1906) and Müller (1907). In-

deed, every biological laboratory is more or less permeated by this spirit of experimental investigation which the recent literature of biology shows may be successfully carried on even without elaborate equipment.

In keeping animals in confinement it is necessary not only to know their habitats, but also their manner of movement and whether they prefer light or darkness and living or dead food. For the investigations upon land animals carried on in the Vienna station, terraria have been constructed with especial care. The sloping bottom of the metal terrarium (Fig. 2) contains soil, with drainage for superfluous water and micro gas burners, or electric bulbs for heating. On one side of the

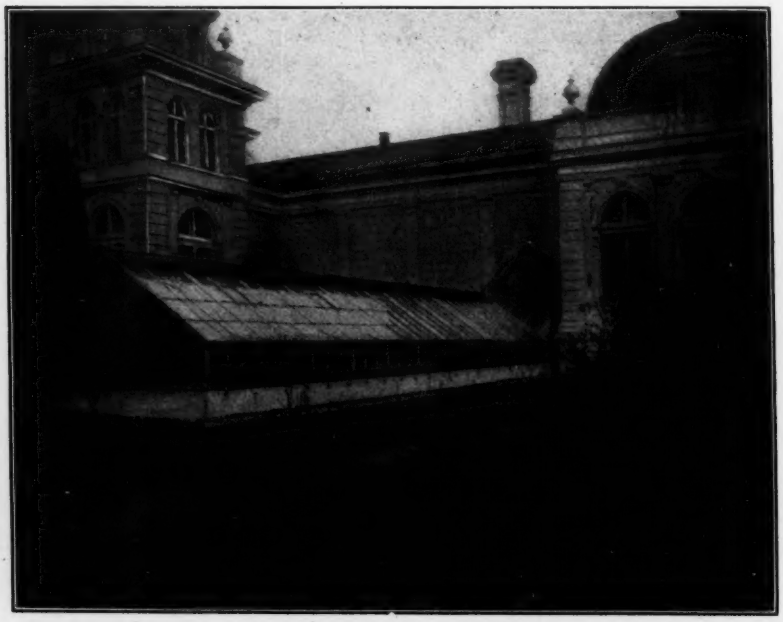


FIG. 5. VIEW OF THE GLASS HOUSE FOR LOW TEMPERATURES.

glazed superstructure and in the roof, ventilating screens are inserted. According to the degree of moisture needed the ground material varies from bran for meal-beetles and clothes-moths, sawdust for cockroaches, clay for bees, wasps and tiger-beetles, fine sand for leaf insects and rove-beetles and common garden soil for earthworms, glow-worms and wood-lice. Plants are used for the production of oxygen and food and with pieces of old bark and branches constitute a natural environment with its grateful shade and hiding places. To provide necessary moisture the ground is sprinkled in the early morning and during the day for the diurnal animals and in the evening for the nocturnal forms. Each day an artificial mist, or rain, is produced in the terrarium atmosphere by means of a hand atomizer or a small compression air pump.

Meal-worms constitute the most useful general food. These larvæ are placed in small, oval, porcelain sugar-bowls which because of their concave sides, prevent escape. For different animals it is necessary to provide scraped meat, fresh ant pupæ, earthworms, snails, flies, kitchen scraps, chopped fruit and vegetables, as well as any small animals available. Careful attention is given to cleaning the cages. The water basins are emptied by siphons and then sponged. The plants in pots and tufts of moss and turf are changed, stones and wood scoured with hot water and the upper layer of sand or earth renewed. Smaller vivaria are employed for special experiments. In these a double cover

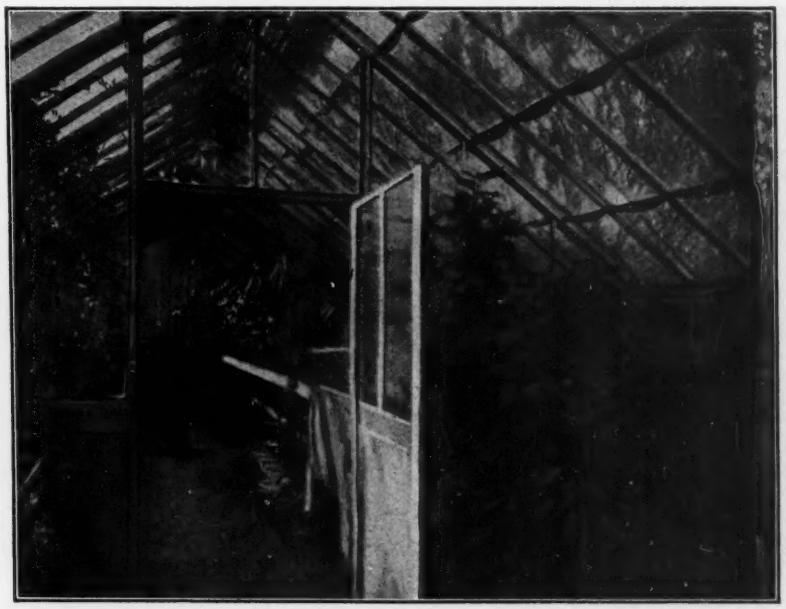


FIG. 6. INTERIOR OF THE GLASS HOUSE FOR LOW TEMPERATURES.

of gauze provides an air space to ensure the circulation of air. The nests of social insects, like bumble bees and burrowing wasps, are transferred from their natural locations in the late evening when all of the family are at home. The insectaria are then placed in moss-covered ditches, or else buried in the earth, and in a few days the insects become quite contented.

In order to mitigate the conditions of confinement which unfavorably affect certain animals there are four large and many small outdoor terraria (Fig. 3).

There is a separate house (Fig. 4), bowed around the north side of the grounds, for heredity researches upon the higher vertebrates. Each of the sixteen cages has an outwardly-sloping cement floor, wire screen ventilators, heating pipes and electric lights, and opens into a garden

plot having trees for the cats to climb in, basins in which swimming birds may disport themselves and soil surrounded with cement walls within which the wild rabbits may burrow. The kangaroos here find ample space in which to run about while snakes and lizards sun themselves on the rock-piles and turtles and frogs alternate between land and water.

The two glass houses (Fig. 5), one adapted for warmth and the other for cold, are in the south portion of the grounds. The glazed superstructure rests upon a thick wall and the floor lies one half a meter below the ground level. Each glass house is divided into a cul-

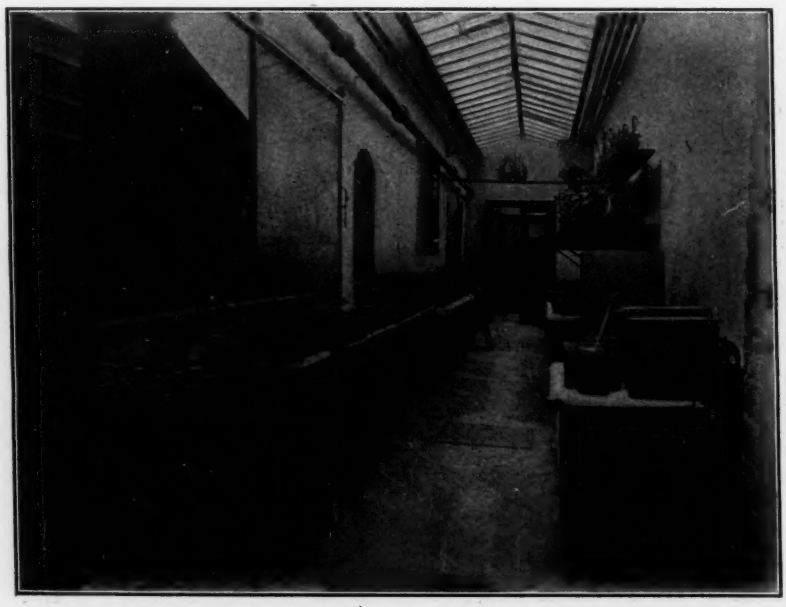


FIG. 7. MIDDLE CORRIDOR OF THE MAIN BUILDING WITH CULTURES OF ALGÆ.

ture room and a preparation room (Fig. 6), the latter being connected with the main building by a glass-covered passage-way. Each culture room is provided with a water and sand bed and a water reservoir sunken in the floor. Electric light enables the experimenter to work continuously when necessary. Venetian curtains are used as a protection from excess of light or cold.

The middle corridor of the main building is covered with a double glass roof. One portion, used as a warm room, contains sweating boxes maintained at various temperatures. In the cold portion (Fig. 7) the conditions are favorable for the culture of fresh water and marine algæ and the various organisms that grow in slime. The garden includes beds for the cultivation of plants for fodder and the experimental work. One large basin (Fig. 8), and four that are smaller, contain the

higher water plants and algæ which grow during the warm season. In the shady, western part of the garden there are six cement basins (Fig. 9), especially for the rearing of plants, and at the same time serving as a home for the hosts of protozoa that wander in and can be used for investigations.

A station for experimental biology must have not only the proper equipment for breeding and rearing organisms under natural conditions, but also for artificially changing and controlling the external factors of the environment. The physico-chemical laboratory (Fig. 10) provides the substances used as variable external factors and also to determine the physico-chemical properties of the biologically important colloids.

FIG. 8. LARGE BASIN IN FRONT OF THE HOUSE FOR HIGHER VERTEBRATES.

These albuminous substances are placed in parchment paper sacks, in closed vessels or in moving water from which the carbon dioxid has been removed and thus for weeks and months are kept free from decay or carbon dioxid or other noxiousness of the laboratory air. A heliostat provides for the penetration of objects with the rays of sunlight and for the ultra-microscopic ends. A nephelometer is used for the estimation of cloudiness whereby errors in physiological observation due to the confounding of comparative and observation fluidities may be reduced. A dilatometer serves to determine the changes in volume and variations in water content of the biocolloids. Then there are pycnometers of all kinds for specific gravity computations and an Ostwald's viscosimeter, in a transparent thermostat, for the determination of the viscosity of

colloid solutions. Especial value is placed upon electrical methods of investigating colloids. A proper distillation plant serves exclusively for providing the purest so-called conducting water. There is an apparatus after Kohlrausch with various electrode vessels for the estimation of the electric conductivity of electrolytes. For the determination of ion concentration in solutions there is a complete contrivance made of brass with electromotor power and having concentration chains with an elongated measuring bridge and a mirror galvanometer with reading telescope. The mechanisms for the calculation of the electric charge of colloids are technically perfected. The conducting apparatus of Landsteiner and Pauli was tested in an investigation

FIG. 9. CEMENT BASINS IN THE GARDEN.

on toxins. Here each colloid, separated from the remaining fluid by the electric permeation, arises and can be easily isolated and tested. Since only the alternating current is found in the institution, two batteries, one of 200 and one of 75 volts, are employed to produce the current. In addition there are the necessary normal and precision thermometers, the instruments for the determination of the freezing point and the coagulation point, precision rheostats, Weston's volt- and ampere-meter, polarimeters and numerous small auxiliary apparatus.

The large general laboratory has fifteen working places fitted with all the usual optical and histological apparatus and reagents. The necessary conditions for the study of the influence of mechanical agencies are enough light, as little dust and infectious material as possible

and sterilizing flames. One line of research is to subject organisms to the influence of different densities in the surrounding medium. For fluids there are basins containing different concentrations of salts, brackish water, etc., with an areometer for measuring the specific gravity of each of the various liquids. For gases there are hand air pumps and means of attachment to the supply pipes of the large electric air-pump located in the cellar. For changing the normal influence of gravitation there are clinostats regulated by clockwork and centrifuges with contact plugs for tapping the electric power wherever needed.

Two dark rooms (Fig. 11) are fitted for studying the influence of light. Both open into a dark corridor from which a triangular door

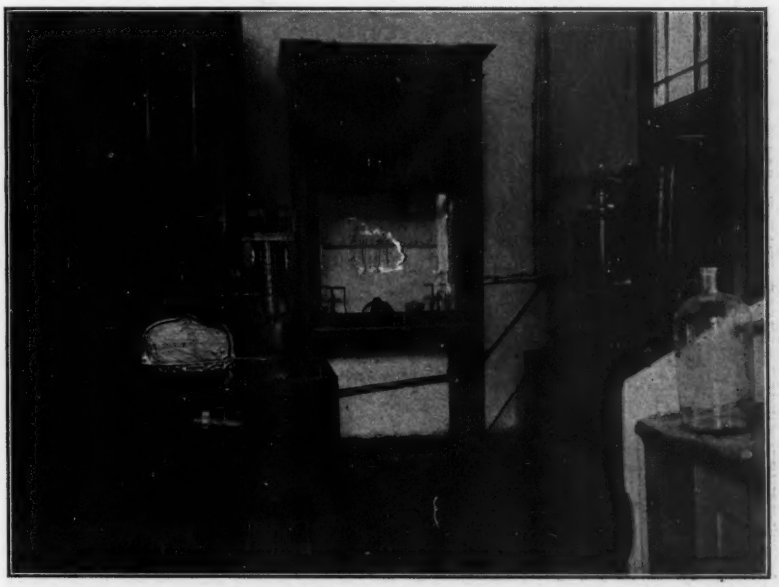


FIG. 10. THE PHYSICO-CHEMICAL LABORATORY.

leads into an anteroom lighted by a red dark-room light. The larger dark room serves for investigations upon the influence of definitely determined lights. Hung up at one end is an arc lamp in which different colored carbons can be used. The elongated form of the room makes possible experiments in which the organisms are placed at different distances from the light source. For investigating the influence of variously colored surroundings, small vivaria are placed in lighted rooms with colored glass covers for direct light, or colored wall coverings, for reflected light. A special apparatus has been constructed for the study of under and over lighting of fishes and amphibia (Fig. 12). For over lighting the aquarium is covered with an enclosing box open above (*o*) and for under lighting the box is closed above (*u*). For in-

creasing the under light there are mirrors (*s*) at an angle of 45° beneath the aquaria. To dispense with these in over lighting a black paper is shoved under the aquarium. Cave animals and fungi are bred and observations made upon etiolated plants and regeneration against the exhalations of various crystals. Through a trap door iron steps descend into a dark vaulted cemented cellar room which is used as a cave. The air is saturated with moisture by water standing on the floor and the temperature is maintained at 12° C.

For all of the purposes of the institution a reliable heating plant is necessary. A central low pressure steam boiler furnishes rather con-

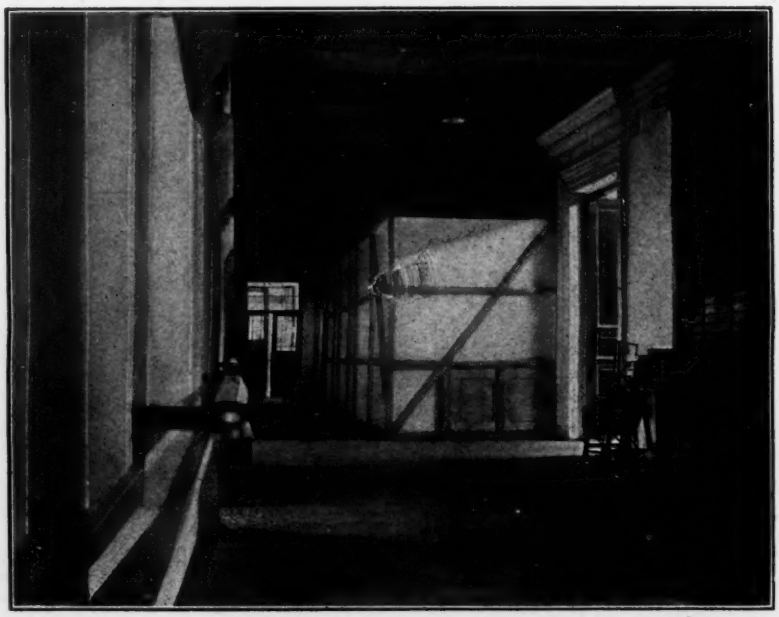


FIG. 11. DARK ROOMS FROM THE CORRIDOR.

stant warmth for the main building, with a warm water system for the glass houses. Small thermostats, which can be exactly regulated, maintain the desired temperature of the different rooms. The northeast half of the building is kept at the ordinary room temperature (17° C.), while the southwest half is warmer and includes seven rooms. In a glazed compartment (Fig. 13) is the highest temperature (37° C.), next the portion of the same room separated by the glass partition (27° C.), then the warm glass house and the warm corridors for terraria and aquaria (20°–25° C.). A large basin is warmed in winter by a tinned tube kept at 10°–12° C.

The Vienna institution for experimental biology is a pioneer in the use of the carbonic-acid cooling machine for maintaining a cold en-

vironment so that different plants and animals can be observed during several generations at specified and perfectly controlled temperatures. Four rooms are kept at + 5° C., + 10° C., + 15° C. and + 20° C. The carbonic acid machine (Fig. 14) produces 5,500 calories hourly.

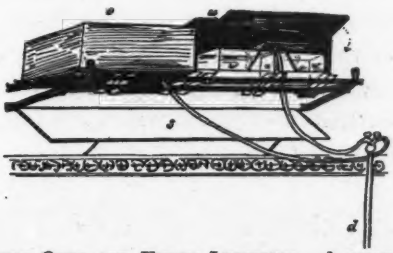


FIG. 12. APPARATUS FOR OVER AND UNDER LIGHTING. *d*, compressed air; *s*, mirror; *o*, box, open above; *p*, box, open below; *w*, glass walls.

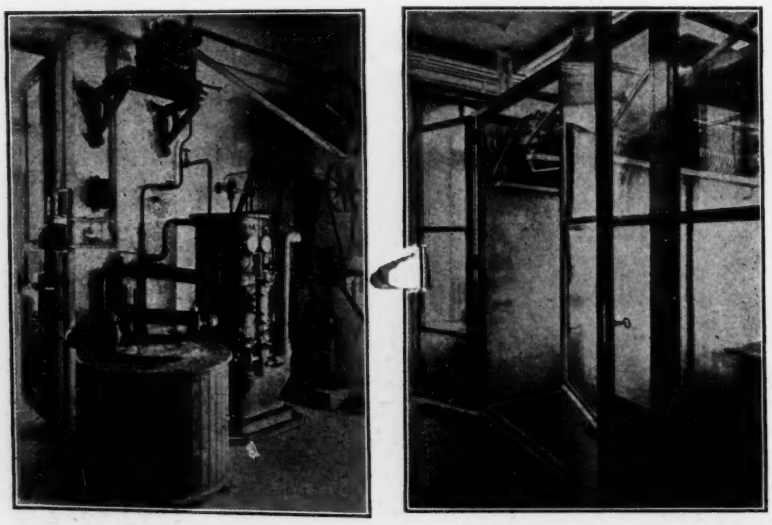
The fluid carbonic acid flows into a wrought-iron spiral core within a carefully isolated receptacle made of tin plate. The salt water surrounding the spiral core is cooled to a low temperature by the sudden

FIG. 13. WARM ROOM WITH COMPARTMENT FOR ELEVATED TEMPERATURE ON THE RIGHT.

expansion of the liquid carbon dioxid. Then the carbonic acid gas is compressed under 55 atmospheres and conducted into a wrought-iron spiral core in the condenser where it is again cooled, liquefied and ready to flow on in the continuous circulation through the machine.

The cold salt water is pumped through the extensive cast-iron radiators of the different cold rooms and the temperature regulators automatically open or shut the valve at the inflow of the cold salt water.

For many years it has been demonstrated, notably in the great Berlin aquarium, that marine animals and plants may be transported a long distance from their native habitats and then live on in aquaria with unimpaired health and growth. Hence it became an essential part of the plan to include marine organisms within the field of work of the institution and a complete equipment was installed for the investigation of problems of marine biology. Natural sea water, from the zo-



A *B*

FIG. 14. *A.* CARBONIC-ACID COOLING MACHINE with condenser, pumps for the compression of carbonic acid gas and for the circulation of the cooled salt water.
B. ONE OF THE COLD ROOMS with the cast-iron radiators for the circulation of the cold salt water.

ological station in Triest, is brought in car loads of thirty casks, each containing 500 liters. It is not difficult to maintain the proper concentration of salts and the same water can be used for years. It is not more expensive than artificial sea water, which is apt to vary in its constitution. Non-corrosive substances like glass, porcelain, glazed clay, cement, wood, hard rubber and lead lined with tin, were used in the construction of the aquaria for sea water. A plan of these aquaria, with the associated apparatus for aeration (Fig. 15), shows the distribution of sea water from the elevated reservoir (*A*), to cement basins (*D*), or to the smaller isolation jars in the next compartment. The effluent water, after being cleansed by running through the filter (*H*), is stored in the subterranean cistern (*K*), and thence driven by the

sea-water pump (Fig. 16), up to the reservoir. The air pump (Fig. 16, *Q*), driven by an electric motor, forces air, which may be diluted by the attachment (*P*), or compressed to five atmospheres (*R*), into five tanks holding 455 liters (*T*), from which, by means of a reducing valve (*U*), it is allowed to escape under a pressure of from 1.1 to 1.2 of an atmosphere and is then distributed (*V*) to the aquaria. In the case of delicate animals, or eggs, solitary or in masses, the air must issue from the terminal plug in very fine bubbles. The outflow is through a plug of bamboo, or merely a piece of finely perforated rubber, while for the larger basins, charcoal or pumice is used. A natural plankton and bottom fauna develops, which is of inter-

FIG. 15. PLAN OF THE SEA-WATER AQUARIA AND THE AERATION EQUIPMENT. *A*, reservoir; *B*, outlet pipe; *C*, ebonite cock; *D*, basin; *E*, *F*, removable outlet pipe and plug; *G*, outlet pipe; *H*, filter basin; *K*, cistern; *L*, riser pipe; *M*, pump; *N*, inlet pipe. Aeration Apparatus: *O*, inlet filter; *P*, attachment for air dilution; *Q*, air pump; *R*, attachment for air compression; *S*, manometer; *T*, air reservoir; *U*, reducing valve; *V*, conducting pipes; *W*, outlet; *X*, flexible connection; *Y*, glass tube; *Z*, excurrent perforated plugs.

est as material for investigation and important as food for animals under experimentation. Such forms appear as small hydromedusæ, ctenophores, worms, ascidians and numerous copepods. Much additional food is required and for this chopped fish, or other meat, is used, but given in small quantities to avoid spoiling the water. Tunicates and mollusks like *Nassa* and *Mytilus*, placed in the larger aquaria, quickly remove the food débris. Protection from the sun is necessary to prevent an excess of green algæ from obscuring the subjects of experimentation. In the small covered jars the proper con-

centration of salts is maintained, after evaporation below the original water level, by regularly adding fresh water from a vessel standing near, so that the temperature will not be altered. The aquarium bottom is varied according to the nature and habitat of the animal being studied. Coarse mussel-shell sand is used for *Amphioxus* and fine slime for marine annelids like *Capitella*. The burrowing animals are protected from direct sunshine. Where the proper bottom is not provided many burrowing animals lose the habit in confinement. Crustaceans are very sensitive to temperatures higher than 22° C. or lower than 6° C. Some kinds of living plants and animals can be transported from the sea simply in moist water-plants. Those of other species must be placed in individual glass containers, each covered with wet parchment paper and packed in a straw basket and all carried in a

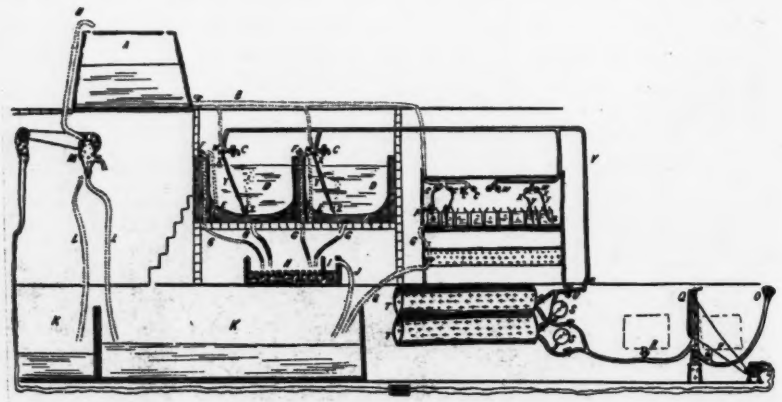


FIG. 16. PUMP FOR THE SEA-WATER CIRCULATION.

large wooden tub. For especially sensitive animals sometimes a steel flask of compressed oxygen, the "hydrobion," is attached to the transport tank. By means of a reducing valve opened at the beginning of the journey, the flow of oxygen is properly regulated. On account of injury in travelling to the apparatus, or to the animals in striking against the outflow tube, it is found more satisfactory to saturate the sea water with oxygen before the journey and so dispense with the "hydrobion."

The aquarial and circulatory system for fresh water is less complicated than that for sea water since it is not so necessary to use the non-corrosive materials in its construction. The water supply, from a height of 2,000 meters, is free from the excess of lime and phosphorus found in the ground water which comes through the Danube alluvium. The rain water, collected in subterranean cisterns, is also used. The more active animals, especially the carnivorous species which chase their prey, require the larger aquaria. An animal 10 cm. long should be

allowed a volume of water of 1 dm^3. Carnivorous fishes, crustaceans and aquatic insects must be of about the same size and only a few in each aquarium. To avoid cannibalism the parents must be separated from the eggs, or spawn and the young, except when the parents brood their offspring. Comparatively small vessels are sufficient for indolent forms like tadpoles, salamanders, aquatic insects and most crustaceans. In most cases when breeding, the larger the tank the more certain the result and the more numerous the progeny. Some animals need stagnant slowly flowing water, others a rapid current, some always live in the water, others only during certain times of the year and still others only during certain stages in the life history. Sharp-angled stones are

FIG. 17. MUSEUM OF THE VIENNA INSTITUTION FOR EXPERIMENTAL BIOLOGY.

necessary for certain fishes and amphibia to scrape against in order to remove from their skins such deadly enemies as the fungus *Saprolegnia*. The annual natural range of temperature must be followed, especially in the breeding of animals. Inhabitants of stagnant pools require a range from 4°–35° C., those of slowly flowing, shallow waters 4°–25° C., of the greater depths 4°–18° C., of rushing, rough mountain brooks with shallow places 4°–15° C. and of caves 12°–17° C. Carnivorous animals need be fed only every other day, and because of the restricted movement in confinement overfeeding leads to fatty degeneration, especially of the reproductive organs. If diseases appear the sick animals must be isolated and the aquaria very carefully cleansed with hot water and the use of disinfectants. *Saprolegnia* and

other ectoparisites are killed by baths of 5 per cent. potassium permanganate, or a light brown solution of ligno-sulphite and ulcerated wounds are touched with a brush, or wad, soaked with concentrated ligno-sulphite.

In the first museums of natural history abnormalities were collected, but later such specimens were discredited as of no value in the system of biological classification and seldom of interest in phylogeny. However, in recent years developmental mechanics has fixed our attention upon the causes of development and by means of the experimental methods many kinds of malformations have been created at will. We now seek the explanation of abnormalities occurring in nature, pro-

FIG. 18.

duced by "nature experiments," and these monsters and variations again become of value as museum specimens. The results of experimentation carried on in the institution are preserved and exhibited in the museum (Fig. 17), in the form of preparations, photographs and wall charts, and in addition preparations from other experimenters and malformations from nature are being collected. Regarded as of primary importance are the results of experiments concerned with development, regeneration, adaptation, variation in instincts, heredity and species transformation in animals and plants. Of secondary importance are the abnormalities of form and color like supernumerary structures, albino or nigrescent individuals, which have not been produced experimentally, and whose cause is unknown, or at most can only

be shown indirectly through analogical deductions. The cases of the museum are located in the entrance hall of the main building and in the adjoining front corridor. Most of the specimens are preserved in fluid, for only a few of the birds and mammals are stuffed and but a minority of the echinoderms and crustaceans are dried. The insects, hermetically sealed in shallow, glass covered cases, represent the influence of temperature upon lepidoptera, of protective resemblance and mimicry, of the series of moultings, of normal growth and growth as influenced by external factors and processes of regeneration, from the egg to the imago. In all cases it is important to have the normal control form exhibited alongside of the experimentally produced variation.

Dr. Przibram publishes a complete list[2] of the animals cultivated in the Vienna institution with important data for each species, concerning the kind of vivarium, or aquarium used, its dimensions and the number of individuals which may there live together, the food, natural habitat and other details, as well as the name of the investigator and publication dealing with each form. The bibliography of papers published by the workers in the institution and Dr. Przibram's summary of these investigations and others being prosecuted furnish an outline of the remarkable scientific productivity resulting from only eight years of research. Such institutions as this of Vienna will do much to solve the great problems of biology. The practise of medical asepsis has permitted operations upon all classes of organisms giving new and valuable data in the field of regeneration. Color has been experimentally investigated as to its nature, whether due to the pigment formation or to the activity of chromatophores, and its relation to light, food, moisture and other external factors as well as its correlation with the animal's vision. By means of the chemical methods of precipitation, agglutination and coagulation, species and hybrids have been tested and the degree of relationship between members of larger groups has been indicated. By the combination of methods of breeding, and subjecting organisms to the influence of changed factors of existence, the laws of heredity will be more clearly established, and the inheritance of functional adaptations acquired under definitely controlled conditions may be demonstrated. The nature of the organ-forming substances in the germ cells and their embryogenesis is being studied. Through physico-chemical methods the biocolloids have become better known and finally the great mystery, the synthesis of living matter itself, may be revealed.

[2] *Zeitschrift f. biol. Technik u. Methodik*, 1910.

THE RELATION OF THE MANUAL ARTS TO HEALTH

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THE relation of the manual arts to health may be considered under two aspects: as they affect the immediate well-being of the pupils and teachers concerned, or in their ultimate influence upon the individual and upon society. Under the former caption belong the hygienic rules pertaining to the performance of the manual occupations in the school, these mostly of negative and precautionary nature The latter relation has to do with the positive contribution which the manual arts are capable of making toward the final attainment of mental and physical health.

Regarding the former, there is probably little to be said that would be new to those who know the manual arts practises from within. The well-trained teachers of this work are aware that the manual arts, inasmuch as they frequently involve "near-work" and sedentary posture, share with other school subjects the danger of injury to eyes, lungs, nervous control and symmetry of form. Teachers of the household arts, for example, appreciate the fact that sewing, in particular, makes demands upon the eyes and the spine of hardly less hygienic import than the much-berated practises of reading and writing. The forward inclination of the head, however occasioned, produces spinal curvature, sub-normal vital capacity and myopia. It is hardly necessary to point out that these dangers are greatly intensified by the use of small models, too fine stitches, dark colored goods, or any materials which, because of a lack of color contrast, make visual discrimination difficult. Professor Schuyten, of Antwerp, investigated the handwork of some four thousand schoolgirls of Belgium and found that about one third testified to visual difficulties in connection with their sewing. Austria has found it necessary to limit by law the fineness of materials which may be used in the manual work of children under ten years of age and to adopt other regulations pertaining to this line of school practise. The German investigators have endeavored to elaborate norms to govern various matters of manual occupations, including posture, delicacy of muscular coordination, kind and amount of light, length of the period of instruction, and its location in the school day.

Teachers of sloyd know that the use of the plane may throw the child into a more unfavorable position than the use of the pen, and

that special and unremitting attention is necessary to minimize the dangers of such incorrect postures. Asymmetrical growth can not be avoided except by a frequent change of muscular tension. Tools and materials must not be pressed against the breast. Ventilation is more important in the shop than in the class room. Sand-paper and injurious colorings should be used as little as possible.

Drawing teachers likewise are now fully cognizant that there are hygienic aspects of their work which can not be safely neglected. For example, the necessity of avoiding accuracy of detail as an aim in the lower grades of instruction, the use of sharp-pointed pencils, intricate models, trying color contrasts, poisonous coloring ingredients, cross-lined paper, etc.

Although all the above requirements and others relating to the internal hygiene of the domestic arts are of extremely great importance and suffer frequent neglect, it is the purpose of this paper to point out some of the larger and more positive relations of the manual arts to national health.

The *problem of vitality* underlies almost every social and political situation confronting us. We are becoming acutely conscious of the possibilities of conservation in the line of health and efficiency. Professor Irving Fisher estimates that of the one and one half million deaths occurring annually in the United States at least six hundred and thirty thousand are due to preventable causes. He computes that the economic loss from these postponable deaths is more than one billion dollars every year. Preventable illnesses are still more numerous and are accountable for the waste of almost another billion per year. The running expenses of tuberculosis alone are sufficient to support six hundred Stanford universities, or three fourths of all the common schools in the United States. Typhoid fever robs us of half as much as tuberculosis. Infant mortality, despite all the advances of preventive medicine, has not appreciably decreased in thirty years. In the most civilized countries from fifteen to twenty-five per cent. of the children do not live to the age of one year, mostly because of parental ignorance and the neglect of a few simple hygienic measures. If our present stock of knowledge pertaining to health prophylaxis were made universally effective the average length of human life would be immediately increased by not less than sixteen years. Certain diseases we know are even now on the wane and the spread of some others has been checked, but the ravages of a few seem to derive impetus from the unnatural strains and conditions of civilized life. Among the latter are, first of all, the nervous disorders of insanity, hysteria and neurasthenia, and, until a few decades ago, the two most wide-spread and terrible plagues of recent centuries, tuberculosis and syphilis.

It is not contended that the physical salvation of the nation is to be

attained solely through the remedy here offered *i. e.*, the extension and proper teaching of the manual arts. The problem is much too vast to admit of any such simple solution. It must be attacked from a hundred angles. The resources of science, education, politics, religion and art will have to be marshaled to this purpose as they have not yet been. There must be persistent and intelligent effort directed at every opening. No one measure nor any set of measures will suffice, and therefore in presenting the claims of the manual arts for recognition in this work let it be understood that no specific, or panacea, is advocated.

Let us consider, however, the contribution which domestic science is capable of making toward this end, and for our purpose let us conceive of domestic science in the broadest possible sense, including all the internal factors that go to mold the home: household economics, the science and art of preparing food, the hygienic oversight of the domestic appointments, the elements of personal hygiene, and most central of all, the care and instruction of young children. Where else can we find an array of subjects promising so much for the well-being of humanity? The problem of national vitality *is* a politico-social, economic-industrial and medico-educational problem, *but it is first and last a problem of the home.* Tuberculosis is a disease of the *home* rather than of the factory or shop, and can not be eliminated short of a material regeneration of household conditions. Typhoid fever will linger after the purification of all water supplies unless the hygiene of the poorer homes is vastly improved. A quarter million of our babies will continue to die every year regardless of progress in the affairs of government, industry and science, unless prospective parents are liberally educated in this most sacred and most difficult of all human duties.

During all the years of plasticity before the child can be reached directly by society through legal or educational measures it is wholly at the mercy of the home. Perfect nutrition, for example, is the foundation stone of happiness and morality as well as our chief defense against disease; and nutrition is an affair of the home. Malnutrition through the period of childhood permits no complete recovery. Efficiency is more dependent upon food and the hygiene of the digestive tract than upon any other one factor. The child that is permitted to bolt its food at the domestic table is not very likely to profit greatly from school instruction in the virtues of mastication. Not less than five to ten per cent. of all school children suffer from imperfect nutrition. They are the ones who develop most readily into nervous wrecks or fall victims of contagious diseases. The hygiene of the mouth alone is considered by Dr. Osler as important from the standpoint of health as the alcohol question. Many of the most important contagious diseases are ingested through this source. Most mouths will continue to be unspeakably dirty until practises of oral hygiene are made habitual

in the home. Ninety to ninety-five per cent. of our school children have one or more defective teeth. The sixth-year molars, as a rule, begin to decay within two years after their appearance. The teeth can only be saved by intelligent attention in the home. An individual's ideals of personal cleanliness are an off-shoot of the semi-instinctive sentiments of disgust and are pretty well molded, once for all, in the years preceding school age.

Again over-stimulation in the early years of childhood will leave its permanent influence upon health and character. A large proportion of parents do not half appreciate the importance of sufficient sleep for children. I have known a four-year-old child to be dragged out to a whist party, there to be kept awake till midnight, and then allowed to drink two cups of strong coffee. Investigations into the hours of sleep of school children show that more than half our school children sleep fewer hours per day than authorities have set as the safe minimum. Innumerable children are kept in a state of semi-intoxication by tea and coffee, drinks which are probably as injurious to the young as beer to the adult. Is it not inevitable that as long as such conditions obtain in the home the legal campaign for temperance will be empty of results, and even the artificial restrictions of vice sorely disappointing? Is it not evident that the first condition of moral development is physical health and perfect emotional balance? Neither the juvenile court, nor the playground, nor ethical instruction in the schools can undo the vicious work of the unfavorable home environment.

All of the above and much besides must be conceived and taught as part of domestic hygiene, which too often has concerned itself exclusively with the externals, such as architecture, plumbing, heating, ventilation, etc. The scope of the subject must be enlarged to include everything having to do with the physical and mental health of the family. In a thousand ways there are intimate and delicate relations of personal hygiene which can be adequately dealt with by no other agency than the home. As an example of this may be mentioned the instruction of children in the functions and hygiene of sex. Society faces few problems more important than this one and, considering the prevailing parental ignorance and neglect, certainly few more difficult ones. Havelock Ellis, after twenty years of scientific investigation of the pathology of sex development, reaches the conclusion that only a small minority of children reach maturity without suffering some of the results of sexual ignorance. The problem is equally one of national health and national morals, as is eloquently but awfully attested by the existence of between one and two million syphilitics in the United States. It is doubtful whether the question of sex hygiene can be satisfactorily solved in this country by instruction on the subject in the public schools, and much is to be said against this solution, but unless

the home can be educated to deal more wisely with the situation than it has yet done it will be necessary for us to follow the example of Italy and certain other countries by placing part of this responsibility upon the schools.

For these and many other reasons, a biological view of human progress counsels us to give more heed to matters of domestic and personal hygiene. Under the present conditions of civilization, more than ever before, man's body, mind and morals are being subjected to difficulties which they were not evolved to meet. Among primitive men, morals were natural and easy, intellectual strain was intermittent and of short duration, while the body throve in its natural habitat of fresh air, sunlight and varied muscular activity. The problem of existence reduced itself chiefly to obtaining food and avoidance of becoming food for others. To-day, conditions are quite the reverse. Possessed of the same animal and egoistic instincts so necessary for the very existence of our ancestors we are required to overcome these in the interests of a higher and more difficult moral standard. The complexity of industrial and social life, with its rivalries, competition and absurdly artificial standards of living, has brought the necessity of *continuous* mental and physical exertion. The body has been exiled from its Garden of Eden to the unnatural and unwholesome environment of house, office, factory and mine. The human body is not exempt from the consequences of the biological law that *the existence of an organism is jeopardized whenever it is exposed to conditions widely different from those which directed its evolution.* Fortunately we are not reduced to a choice between extinction, on the one hand, and a return to nature, as advocated by Rousseau, on the other. A diligent application of the laws of personal and social hygiene will preserve us from this dilemma. Nothing else will, and the contribution of domestic science to this end is absolutely essential to its ultimate success.

Almost if not quite as much can be said for that branch of the manual arts technically designated as *manual training.*

Ever since Seguin's classical experiments with manual training in the education of feeble-minded children, nearly three quarters of a century ago, the school has moved rapidly toward a clearer recognition of the close inter-relation between mind and body. For hundreds of years education had been controlled by a bifurcated educational aim, with most of its emphasis on the side of mind. In the last few years, however, the psychologists have learned a great deal about the motor aspects of mental activity. They have demonstrated that almost any simple act of attention involves muscular innervation and, contrariwise, that motor exercise quickens intelligence. Psychology teaches that body and mind have grown up together and that the latter has no *raison d'être* apart from motor adjustment. When educational practise

neglects either aspect of the duplex organism with which it deals, the results are bound to be unsatisfactory.

Let us consider more specifically *the contribution of the manual arts to the attainment of perfect mental balance.* Statistics are unanimous that insanity, hysteria and neurasthenia are rapidly increasing in all civilized lands. Now, the newer psychological interpretations of insanity are of the utmost suggestiveness for education. Originally, the insane person was thought to be possessed of devils, cursed of God, etc. Later the scientific studies in neurology led to the theory that insanity in all cases is due to lesions of the brain: to actual degeneration of the nervous tissues induced by hypothetical toxins of disease. This is demonstrably true for certain forms of insanity. But for a very large proportion of insanities and for most, if not all, of that border-line group designated in psychiatry as the *psychasthenias,* the theory of lesions remains absolutely without positive confirmatory evidence. In regard to these the belief is rapidly gaining ground among psychiatrists that we have to do not with diseased tissues in the ordinary sense, but rather with *disturbances of function* which in greater or less degree are amenable to correction by the so-called "method of re-education." This system of therapeutics has already proved successful in numberless cases of *depression, hysteria* and *neurasthenia,* and is believed by America's leading authority on insanity, Dr. Adolph Meyer, to be hardly less applicable to the form of adolescent insanity known as *dementia præcox.* Recent extensions of our knowledge of this disease are so pertinent to our theme as to warrant a brief discussion of it here. *Dementia præcox* is one of the most interesting forms of insanity for three reasons. In the first place, it is extremely common, accounting for some thirty per cent. of the total admissions to insane hospitals. In the second place, it does not prey upon the old or mentally decrepit and is not allied in any way with the diseases of immorality. Instead, it attacks the youth, and not infrequently the youth of most marked intellectual promise. In the third place, some of the newer studies of the disease show that it is due to definite ascertainable *functional* disturbances of the individual's mental evolution and that it will yield to the right kind of educational treatment. As characterized by Dr. Meyer, *dementia præcox* is "a miscarriage of instincts through lack of balance"; a deterioration of habits, "due to progressively faulty modes of meeting difficulties." We are informed further that it is most likely to develop in the youth of the "repressive type," characterized by seclusiveness and what is likely to be taken for "depth of thought." It usually involves fantastic day-dreaming, sexual imagination, brooding over disappointments and (the most central symptom) *a discrepancy between thought and action.* As described by Dr. Meyer:

There develops an insidious tendency to substitute for an efficient way of meeting difficulties a superficial moralizing and self-deception, and an uncanny drift into so many varieties of shallow mysticism and metaphysical ponderings, or into fantastic ideas which can not possibly be put to the test of action. All this is at the expense of really fruitful activity, which tends to appear insignificant to the patient in comparison with what he regards as far loftier achievements. Thus there develops an ever-widening cleavage between mere thought life and the life of actual application such as would bring with it the corrections found in concrete experience. Then under some strain which a normal person would be prepared for, a sufficiently weakened and sensitive individual will react with manifestations which constitute the disorders of the so-called "deterioration process," or *dementia præcox*. Unfinished or chronically sub-efficient action, a life apart from the wholesome influence of companionship and concrete test, and finally a progressive incongruity in meeting the inevitably complex demands of the higher instincts—this is practically the formula for the deterioration process.[1]

The following is Dr. Meyer's clinical description of a typical case:

She began school at seven years, was smart, and applied herself well, but at the age of eleven she seemed to be failing and was thought to be studying too hard. She grew thin, seemed nervous, and complained of headaches. At twelve she was in poor health. . . . [later] She was disappointed at home, for some time dreamt of becoming a teacher, but soon sank into hypochondriacal ruminations, and finally, at twenty-one, after useless operations, passed into a confused religious excitement, followed by stupor, in which she sits inactive and irresponsive, *with the top-heavy and yet empty notion of being good, of saving the world,* etc.

The next few decades may witness the complete demonstration that such cases can usually be saved by being taken early in hand and trained to more complete activity and appropriate self-objectification.

But, as already indicated, the importance of this principle of the sanifying influence of wholesome activity does not lie merely or chiefly in the insurance it offers against outright insanity. Sanity, be it remembered, is a relative term, and therefore the importance of manual training in this connection goes far beyond its prophylactic value as an insurance against admission to an insane hospital. In a sense no one is perfectly sane. A noted American psychologist, after making a careful inventory of his absurd crotchets, phobias and other mental extravagances, pronounces himself insane on at least seventeen different counts! It is doubtful whether many of us, if truly honest with ourselves, could make any better claim to perfect sanity. Just as there are millions of physically inefficient persons who are in no immediate danger of death, and relatively few who are perfect of body, so there are no end of people who are in no danger of trial for lunacy, but who nevertheless are decidedly below their own best level of mental balance. *Dementia præcox* has been mentioned at length only because it reveals, writ large, what to a less degree is true of most of us. The causes which

[1] Adolph Meyer, in the *Psychological Clinic*, 1908, pp. 96–97.

produce complete deterioration in the individual of nervous instability may, in the person of better hereditary endowment, result in nothing more serious than a temporary nervous break-down, "a slump of relative inactivity" (Meyer), or some other manifestation tending to rob life of its due zest and render success more difficult. To escape such dangers, every individual needs to be taught to "avail himself of the power of the concrete." We must find for every child the level where he can function successfully if we would have him escape the shocks of disappointment, the habits of failure and the resulting inactivity, day-dreaming, vain wishing and chasm between thinking and doing. It behooves us "to make doing just as attractive as knowing," and to explore ways and means of enlarging the child's opportunities for the accomplishment of simple, wholesome and enjoyable things. Every person can be taught to do something well and take pleasure in doing it, and the result will contribute much more to the person's own mental balance and to the welfare of the world in general than will a smouldering volcano of sentiment and frothy, but inactive desire.

WHAT MASTERPIECES OF GREEK SCULPTURE WERE KNOWN TO THE MEN OF THE RENAISSANCE? A CENSUS

By EDWARD S. HOLDEN

U. S MILITARY ACADEMY

SOME popular writers on the Renaissance give, and seek to give, the impression that the sculpture known to the Renaissance was pure, high Greek, and that these masterpieces set all Italy astir. Scholars know better, but most of us are not scholars.

All my life I have been bullied by statements of the sort, and at last the worm has turned and has consulted the scholars, as it should have done long ago. The following paragraphs will seem of very slight importance to the few students who know, but they may have some interest to others. If I—no scholar—knew where the data which I have here tabulated could be found collected, such paragraphs might well be quoted. But I do not know, and many others are probably as ignorant as I. It is for them and myself that I am writing, making every apology to the real scholars; and in partial excuse, asking them why I have not been able to find such tables as I here give in some handbook or manual.

Here follow a few quotations from writers on the fine arts of the Renaissance. All of them give the scholar's point of view. For brevity, I have sometimes ventured to summarize them.

> Whatever may be the facts of to-day, the eye of Europe in the middle ages was not accustomed to Greco-Roman forms in art. In Spain, France, Germany or Britain, the Roman ruins were even then so rare . . . that any knowledge of them . . . was out of question. In Italy, Roman ruins were no rarity, and in Rome they were abundant, but the idea of copying them never suggested itself to an Italian of the middle age. That antiquarian and historic interest in relics of the past, which is so natural to us, is an interest which dates from the Renaissance. To the middle age the ruin was a quarry; nothing more.[1]

How the interest in the literature of the ancients brought about a revival in the arts—architecture, painting, sculpture—need not be recited here. The story has been told a thousand times. One point may be emphasized, perhaps. The share of science in the revival has not been sufficiently recognized by most writers on the period. The name of Copernicus, for instance, is not mentioned in the index of any

[1] Goodyear, "Renaissance in Modern Art," p. 49.

standard work that I have seen excepting by Symonds.[2] Yet Copernicus came to Rome to study astronomy with a company of Roman doctors; the schools of Italy were then alive with inquiry. When he published his monumental book in 1543 he found a host of readers prepared to comprehend his theory of the world.

The interest in ancient art had its foundations in literature and archeology. Biondo's treatise on the monuments of ancient Italy was written before 1463. In 1462 Pius II. issued a bull protecting the remains of ancient Rome from further depredations. The Museum of the Vatican was founded by Julius II. (1503–13).

The appreciation of classical sculpture was quickened by the recovery of many ancient works. Many? Not many of high class. The Apollo Belvedere was set up by Pope Julius.

Michel Angelo saw the Laocoön disinterred from the ruined Baths of Titus. Leo X. (1513–21) acquired the reclining statues of the Nile and the Tiber, and the so-called Antinoüs. These and other specimens of classical art, though not representative of that art at its best, helped to educate Italian taste, already well disposed towards every form of classical culture. The Latin verse-writers of Leo's age show the impression made by the newly found works of sculpture.

It is more interesting to note the remark of an expert, the Florentine sculptor Ghiberti, who, in speaking of an ancient statue which he had seen at Rome, observes that its subtle perfection eludes the eye, and can be fully appreciated only by passing the hand over the surface of the marble.[3]

Ghiberti (died 1455?) made a collection of antique marbles, which was inherited by his grandson, and on the death of the latter sold and dispersed.[4]

Donatello (died 1466?) and Brunelleschi were known as "treasure-seekers" and they exhumed many fragments of cornices, capitals and bas-reliefs, coins and the like. Of these Donatello made drawings and studies, while Brunelleschi journeyed from Florence to Cortona to see a sarcophagus in the Duomo, of which Donatello had given him a glowing description.[5]

Michelangelo's introduction to Lorenzo de' Medici came about through a copy which the lad had made from the antique (the head of a Faun, now in the Uffizi) about 1489, and for three happy years Michelangelo lived and studied in the studio-garden among the examples of ancient statuary which the duke had brought together.

The one antique fragment which seems to have roused his enthusiasm . . . was the Belvedere Torso. The Laocoön does not seem to have greatly moved him.[6]

[2] See "The Renaissance of Science," *The Popular Science Monthly*, November, 1903.

[3] Sir Richard Jebb in "Camb. Mod. Hist.," Vol. I.

[4] Perkins, "Tuscan Sculptors," I., p. 136.

[5] *Ibid.*, p. 139.

[6] *Ibid.*, Vol. II., p. 7.

Athens was in the possession of Italians from 1387 until it was captured by the Turks in 1458, and during that interval a few scholars visited the city. After 1450 all is darkness until 1674, when the Frenchman Jacques Carrey made his drawings of the Parthenon.

Its sculptures could hardly have been known to the men of the Renaissance. A few of the greatest statues were known to Michelangelo—the Torso of the Belvedere especially, and he declared himself its pupil. This figure was one of the chief promoters of the Renaissance in sculpture.[7]

> The especial reverence for classical antiquity, which in former times so exclusively prevailed, invested every fragment of ancient sculpture, even the most trivial, with a sentimental importance. . . . The antique had comparatively little to do with the truly great Italian school of sculpture of the fifteenth century. . . . External nature, religious feeling, human character and expression, these were alike the school, and in a far greater measure than the antique, the inspiring motives, of (Ghiberti, della Quercia, Donatello, Luca della Robbia, Verocchio and a long list of splendid names).[8]

Winckelmann's "History of Ancient Art" appeared in 1764, after long years of preparation. Pater says:

> It is since his time that many of the most significant examples of Greek art have been submitted to criticism. He had seen little or nothing of what we ascribe to the age of Pheidias; and his conception of Greek art tends, therefore, to put the mere elegance of the imperial society of ancient Rome in place of the severe and chastened grace of the *palæstra*. For the most part he had to penetrate to Greek art through copies, imitations, and later Roman art itself . . . a turbid medium.[9]

The foregoing extracts give the true doctrine. Roman art, not Greek, furnished the inspiration of the Renaissance sculptor, speaking generally. The tables that immediately follow furnish a striking proof.

Dates at which Seventy-six of the most Celebrated Statues were Found—Unearthed

A selection was made of seventy-six of the most famous statues of Greece, and from Mr. Edward Robinson's scholarly catalogue of the casts of the Boston Museum the dates at which these statues became known to the world were set down.

The little table follows:

[7] Robinson, Boston Museum Catalogue, p. 324.

[8] "Italian Sculpture of the Middle Ages," introduction by J. C. Robinson, superintendent of the art collections of the South Kensington Museum, London (1862).

[9] W. Pater, "Renaissance," p. 205.

Fifteenth Century and Earlier

Statue	Now in	Unearthed in
Apollo Belvedere	Rome	fifteenth century?
Boy with thorn	Rome	before 1471
Venus—Medicean	Florence	(?) (Müntz)

Sixteenth Century

Aphrodite (Knidian)	Rome	before 1700
"Dying Gladiator"	Rome	sixteenth century
Fighting Persian	Rome	1514
Laocoön	Rome	1506
Belvedere Torso	Rome	sixteenth century
Idolino	Florence	1530
Sleeping Ariadne	Rome	sixteenth century
Artemis—Versailles	Louvre	sixteenth century
"Germanicus"	Louvre	sixteenth century?
Arringatore	Florence	sixteenth century?
Wrestlers	Florence	1583
Hermes Belvedere	Rome	about 1542
Silenos and Dionysos	Louvre	sixteenth century
Niobe	Florence	1583
Ilioneus	Munich	1556–63
Niobid	Rome	sixteenth century

Seventeenth Century

Fighter of Agasias	Louvre	1605–21
Venus Genetrix	Louvre	about 1650
Faun—Barberini	Munich	1623–44
Ares resting	Rome	before 1633
Venus of Arles	Louvre	1651

Eighteenth Century

Discobolus of Myron	Rome	1791?
Pericles (?)—bust	British Museum	1781
Spear-bearer of Polykleitus	Naples	1797
Faun—Capitol	Rome	1701
Mercury resting	Naples	1758
Antinoüs	Rome	eighteenth century
Venus—Capitol	Rome	1752
Venus—Capua	Naples	1756
Venus—crouching	Rome	1760
Aktaion—attacked	British Museum	1774
Apollo with the lizard	Rome	1777
Zeus—Otricoli	Rome	end of century
Apollo with the lyre	Rome	1774
Clio	Rome	1774
Thalia	Rome	1774
Standing Discobolus	Rome	1792
Discobolus	British Museum	1791

NINETEENTH CENTURY

Harpy Tomb	British Museum	1838
Ludovisi Throne	Rome	1886
Herakles shooting	Munich	1811
Herakles and the apples of the Hesperides	Olympia	1876
Charioteer	Delphi	1896
Eleusinian Deities	Athens	1859
Amazon	Berlin	1868
Monument of Dexileos	Athens	1863
Hermes of Praxiteles	Olympia	1877
Hermes of Andros	Athens	1833
Charioteer (Mausoleum)	British Museum	1857
Mausolus	British Museum	1857
Demeter (Knidus)	British Museum	1858
Column-Drum (Ephesus)	British Museum	1871
Hypnos	British Museum	1855
Apoxyomenos	Rome	1849
Sophocles	Rome	about 1839
Winged Victory	Louvre	1863
Eubuleus (?)	Athens	1885
Venus of Melos	Louvre	1820
Battle of the gods and giants (Pergamon)	Berlin	1879–80
Diadumenos (Delos)	Athens	1894
"Athena thinking"	Athens	1888
Dancing Faun	Naples	1830
Warrior (Delos)	Athens	1882
Silenos	Athens	1862
Boxer resting	Rome	1885
Augustus Cæsar	Rome	1863
Young Apollo	Berlin	about 1880
Young Dionysos	Rome	1881
Nereids	British Museum	1838
Nike of Paionios	Olympia	1875
Apollo and the Omphalos	Athens	1862
Marsyas (after Myron)	Rome	1823
Venus—Esquilene	Rome	1874

It appears that of the seventy-six most famous monuments there were found:

In the fifteenth century or earlier	3 statues
In the sixteenth century	16 statues
In the seventeenth century	5 statues
In the eighteenth century	17 statues
In the nineteenth century	35 statues
Total	76 statues

The statistics of a list of *all* statues would not serve our purpose as well as this enumeration, which relates only to the most celebrated works. The men of the Renaissance knew barely a score of the great statues. Roman copies of Greek originals were known to them, and a few of the great originals themselves. But how few they were!

THE PROGRESS OF SCIENCE

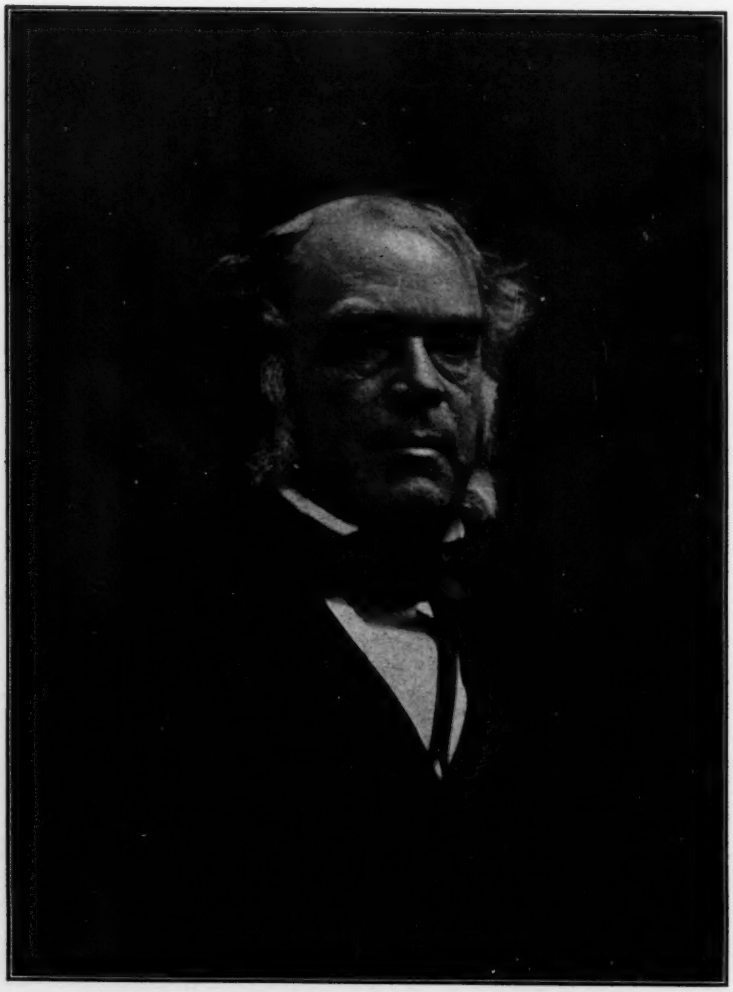
MEETINGS OF SCIENTIFIC SOCIETIES

APART from the Christmas holidays, the month of April is the favorite season for scientific meetings. It would be the best time in the year, if it were only possible for educational institutions to agree on a week's holiday. At present some of them have a vacation at a regular time, some follow Easter and some have none. There is now active discussion on the reform of the calendar. One month with twenty-eight days is certainly undesirable, and it would be convenient if each month began on the same day of the week. A radical reform is no more unlikely than any other, and the suggestion made by Professor T. C. Chamberlin (*Science*, November 25, 1910) is alluring. It is to have twelve months of 28 days with an extra week at the close of each quarter, Christmas week having an added day with another extra day on leap year. Southern nations may be over-fond of holidays, but life is almost too monotonous in the sober north. It might be well if each quarter were followed by a week in which the routine business of life were interrupted—Christmas week for family reunions, Easter week for religious and scientific gatherings, Julien week for national and international celebrations, the autumn week for harvest and labor festivals. While we wait, probably in vain, for such a reform, educational institutions might, and to a certain extent have adopted the plan of four quarters with a week's intermission. Concentrated effort might give us a week in the spring for scientific meetings.

The National Academy of Sciences holds its annual stated meeting in Washington, beginning on the third Tuesday in April, and almost justifies its existence by the time of meeting, as members from further north are likely then to come into the fullness of the spring. The academy is in the main of interest to its limited membership. It is possible that the honor of election stimulates to scientific research, though it can scarcely be so effective in this direction as would be the case if the work of the academy were better known and if there were some more tangible advantage in membership, as is the case in some of the continental academies, where the members receive salaries from the government. If research is to be accomplished it must be paid for in some way, and there is much to be said for the endowment of individuals through an institution such as the National Academy of Sciences.

At present the official function of the academy as the scientific adviser of the government is hardly exercised. Indeed it is not clear how it could be to advantage when the government has in its own employment hundreds of scientific men. Nor can it be said that the programs of scientific papers are of great interest. Important research work is presented each year, but probably not more important than before the special scientific societies, and it has now become very difficult for scientific work in all directions to be presented before a single group of individuals.

Following the meeting of the National Academy in Washington, the American Philosophical Society of Philadelphia has in recent years arranged a meeting which has assumed national importance. The program of scientific papers is larger than at Washington, the society is fortunate in



having its own historic building for its meetings, and the city is generous in its hospitality. The papers presented are of the same high standing and the same mixed character as at Washington.

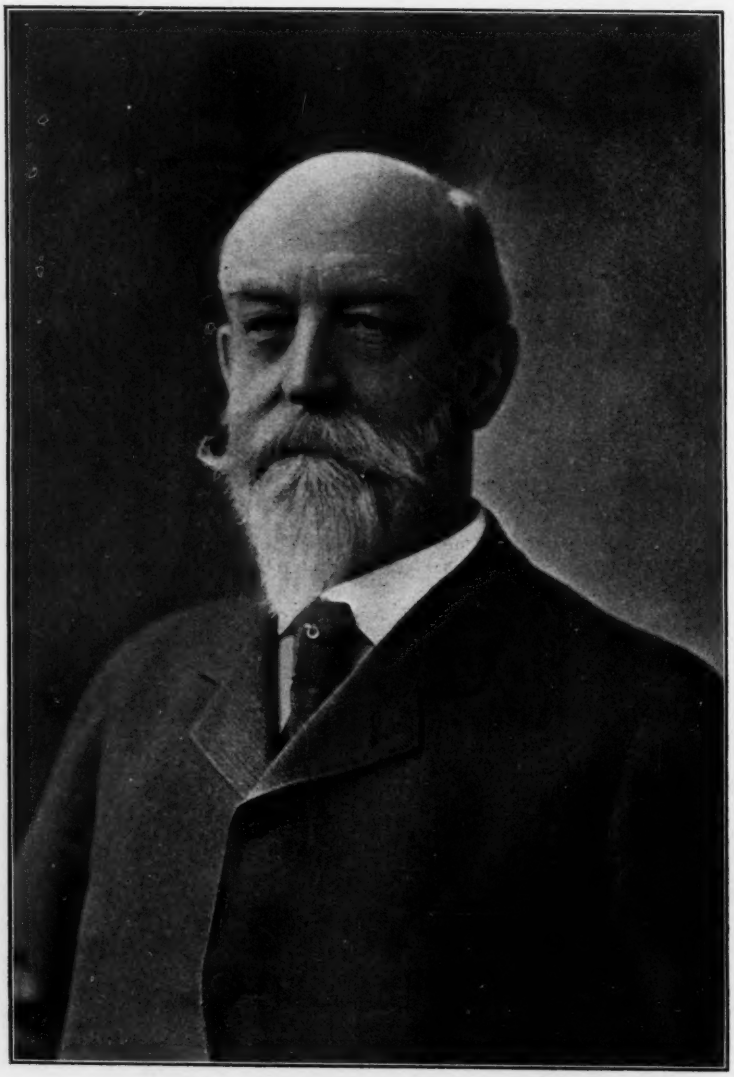
The spring is also the time chosen for the meetings of some of the state academies of science. A glance at the program of one of these, such as the Michigan Academy of Sciences, shows that it contains an almost bewildering array of papers. These are, however, presented before several sections and thus have a more homogeneous attendance and better chance for discussion. An interesting event this year was the joint meeting of the different scientific and learned societies of California, which will doubtless hereafter become an annual event on the Pacific coast.

THE CENTENARY OF THE BIRTH OF JOHN WILLIAM DRAPER

THE centenary of the birth of John William Draper, which occurred on the fifth of May, was celebrated with adequate ceremonies and addresses by New York University, where he was professor from 1837 until his death in 1882, and where two of his sons were also professors.

Draper was the son of an English Wesleyan clergyman. He came to America at the age of twenty-one, and graduated as doctor of medicine from the University of Pennsylvania in 1836. His work covered a wide field. He made important researches in chemistry, physics and physiology. He wrote text-books and taught these subjects, being a leader in medical education. He took an important part in the development of two of the most important advances of applied science —electrical telegraphy and photography. Later he turned his attention to philosophical and historical subjects. His history of the intellectual development of Europe and his history of the conflict between religion and science have been widely read and are of great

AUTOTYPE COPY OF THE EARLIEST SUNLIGHT PICTURE OF A HUMAN FACE.
Miss Dorothy Catherine Draper, taken by her brother, Professor John William Draper, M.D., LL.D., early in 1840. The original daguerreotype is the property of Sir William John Herschel.



HENRY PICKERING BOWDITCH.

influence, having appeared in many editions and having been translated into a dozen different languages. Finally he devoted ten years of his life to a history of the American civil war.

Draper's early scientific work was concerned with the chemical action of light. In 1837 he investigated the growth of plants exposed to the light of the solar spectrum. He at that time also studied the action of light in changing the color of metallic salts and applied the photographic process to the solution of physical problems. When Daguerre's discovery was announced he improved the process and took in 1840 the first portrait of the human face, at a time when this was regarded as impossible in Europe. In the same year he took the first photograph of the surface of the moon. Draper was also the first to obtain photographs of the diffraction spectrum, and of the ultra-red and ultra-violet lines. In 1857 he wrote that the occurrence of lines in the spectrum is connected with the chemical nature of the substance and that "if we are ever able to acquire certain knowledge respecting the physical state of the sun and other stars, it will be by an examination of the light they emit." It is an interestitng fact that his son, Henry Draper, in 1872, was the first to obtain photographs of the fixed lines in the spectra of stars.

Draper's work in physiology was of importance; he made many new discoveries and consistently used physico-chemical explanation in the place of the vitalism of those days. In like manner he applied causal principles to the evolution of society. Draper played an important part in the development of modern science at a time when America was represented by but few leaders.

HENRY PICKERING BOWDITCH

HENRY PICKERING BOWDITCH was a member of one of those families which in Boston and in Philadelphia have maintained the traditions of the English aristocracy. His grandfather was the eminent mathematician, Nathaniel Bowditch, and his father and his brothers have like himself always been ready in the performance of public service. Bowditch was born in Boston in 1840; on graduating from Harvard College in 1861 he volunteered for service in the civil war, and at its close retired as major of the Fifth Massachusetts Cavalry. He then passed through the Lawrence Scientific School and the Harvard Medical School and spent three years abroad working under Carl Ludwig at Leipzig. When he returned to Boston in 1871 the chair of anatomy and physiology held by Oliver Wendell Holmes was divided, physiology being assigned to Bowditch. For thirty-five years he was a leader in education and research in the medical sciences, and the physiological laboratory that he founded was the pioneer of laboratories in the medical sciences. He was largely responsible for the medical school building, completed in 1883, the laboratories of which were admirably equipped for that time, and again was largely responsible for the magnificent buildings and laboratories of the new medical school opened in 1906, the year in which, owing to failing health, he became professor emeritus. As dean of the medical school and in other ways he exercised an enormous influence on the improvement of medical education and medical science in this country. His own researches on the growth of children, on vision, on the knee jerk and on other subjects were of great importance, but in a brief biographical notice, it seems more fitting to dwell on his great public services for physiology, for medical education, for the city and for the country. Of his personality Professor Charles S. Minot, a student under him and for many years his colleague, says: "He found great happiness in his home life, in his children and grandchildren, and also in the numerous friends, whom he attached not only by his unusual abilities

but by his personal charm. He was social by nature, keenly humorous, warm and faithful in his attachments, full of the zest of life. He was profoundly modest and seemed never to know how high his abilities were estimated by others. He never quarrelled, but was for every good cause he championed a good fighter. Perhaps his most distinguishing trait was his remarkable combination of keen practical sense in the use of means with enthusiasm in the pursuit of ideal aims. With all his buoyant vitality, with all his eager interest in men and affairs, he was essentially an idealist, who won the love and admiration of many friends both in Europe and America."

SCIENTIFIC ITEMS

WE record with regret the deaths of Dr. Herman Knapp, professor emeritus of ophthalmology in Columbia University; of Dr. Charles Stedman Bull, professor of ophthalmology in the medical department of Cornell University; of Mr. T. Rupert Jones, F.R.S., formerly professor of geology at Sandhurst; of Major George Lamb, director of the Pasteur Institute of India, and of Dr. Pehr Olsson-Seffer, botanist of the Mexican government, murdered by brigands in the Mexican insurrection.

AT the meeting of the National Academy of Sciences on April 20, the following were elected to membership: Edward Emerson Barnard, astronomer, Yerkes Observatory, Williams Bay, Wis.; Edward Burr Van Vleck, professor of mathematics, University of Wisconsin; John Filmore Hayford, director of the College of Engineering, Northwestern University; Edwin Herbert Hall, professor of physics, Harvard University; Julius Oscar Steiglitz, professor of chemistry, University of Chicago; Bertram Borden Boltwood, professor of radio-chemistry, Yale University; James Furman Kemp, professor of geology, Columbia University; Arthur Louis Day, director of the Geophysical Laboratory of the Carnegie Institution; Robert Almer Harper, professor of botany at the University of Wisconsin. Foreign associates were elected as follows: Professor Ernest Rutherford, University of Manchester, England; Professor Vito Volterra, University of Rome, Italy. At the annual dinner of the academy on April 19 the Draper Gold Medal was presented to Mr. C. G. Abbot, of the Smithsonian Institution, for his researches on the infra-red region of the solar spectrum and his accurate measurements, by improved devices, of the solar "constant" of radiation.

SIR J. J. THOMSON, Cavendish professor of experimental physics in the University of Cambridge, and Dr. D. Hilbert, professor of mathematics at Göttingen, have been elected corresponding members of the Paris Academy of Sciences.

DR. FREDERIC A. LUCAS, curator in chief of the Museum of the Brooklyn Institute, and formerly curator of the U. S. National Museum, has been elected director of the American Museum of Natural History.—Dr. Elmer Ellsworth Brown, U. S. Commissioner of Education, has been elected chancellor of New York University.

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

ABBE, CLEVELAND, The Meteorology of the Future, 21
Academic and Industrial Efficiency, 100
Agriculture, The Relation of, to Biology, F. R. MARSHALL, 539
"Albatross," Work of the, in the Philippines, ALBERT I. BARROWS, 241
Alcohol—its Use and Abuse, GRAHAM LUSK, 381
American Indians, Language of the, A. L. KROEBER, 500
Arts, Manual, in their Relation to Health, LEWIS M. TERMAN, 602

BARROWS, ALBERT I., The Work of the "Albatross" in the Philippines, 241
Biology, The Relation of, to Agriculture, F. R. MARSHALL, 539; Experimental, Vienna Institution for, CHARLES LINCOLN EDWARDS, 584
Birth Rate, Diminishing, Is it Volitional? CHARLES FRANKLIN EMERICK, 71
Bowditch, Henry Nathaniel, 617
Bridges, Natural, North American, The Formation of, HERDMAN F. CLELAND, 417
Brooks, Professor, Philosophy of, EDWARD GLEASON SPAULDING, 120

Carnegie Institution, Research Work of the, 411
Cavendish Laboratory of Cambridge University, 517
Century Plants, The Smallest of the, WILLIAM TRELEASE, 5
Chandler, Dr. C. F., Bronze Bust of, 413
CHASE, WILLIAM, Freud's Theories of the Unconscious, 355
Chemistry, The Work of, in Conservation, ELBERT W. ROCKWOOD, 291
Child, Motor Education for the, J. MADISON TAYLOR, 268
Circulating Professors, 516
CLELAND, HERDMAN F., The Formation of North American Natural Bridges, 417
COCKERELL, T. D. A., Reality and Truth, 371
College, Professor, The Case of the, WARNER FITE, 273; Graduate, of Princeton University, 307
Conservation, The Work of Chemistry in, ELBERT W. ROCKWOOD, 291
Consulting Psychologist, C. E. SEASHORE, 283
Control of Plant Diseases, Progress in, F. L. STEVENS, 469
Cost of Living, HENRY PRATT FAIRCHILD, 377
Credits, College, Scientific *versus* Personal Distribution of, WILLIAM T. FOSTER, 388

DAVENPORT, C. B., Euthenics and Eugenics, 16
DAVIS, W. M., Disciplinary Value of Geography, 105, 223
Dismissing Professors, 305
Distribution of College Credits, Scientific *versus* Personal, WILLIAM T. FOSTER, 388
Draper, John William, Centenary of the Birth of, 616
Dynamics of a Golf Ball, J. J. THOMSON, 184

Education, Motor, for the Child, J. MADISON TAYLOR, 268
EDWARDS, CHARLES LINCOLN, Vienna Institution for Experimental Biology, 584
Efficiency, Industrial and Academic, 100
Ehrlich's Specific Therapeutics in Relation to Scientific Method, FIELDING H. GARRISON, 209
EMERICK, CHARLES FRANKLIN, Is the Diminishing Birth Rate Volitional? 71
Emerson, Ibsen and Nietzsche, the Individualists, LEWIS WORTHINGTON SMITH, 147
Euclid's Geometry, Is it merely a Theory? EDWARD MOFFAT WEYER, 554
Euthenics and Eugenics, C. B. DAVENPORT, 16
Evolution, and Kant, ARTHUR O. LOVEJOY, 36; of Nations, Geographic Influences in the, WALTER S. TOWER, 164
Experimental Biology, Vienna Institution for, CHARLES LINCOLN EDWARDS, 584
FAIRCHILD, HENRY PRATT, The Cost of Living, 377

FITE, WARNER, The Case of the College Professor, 273
FOSTER, WILLIAM T., Scientific *versus*

Personal Distribution of College Credits, 388
France, Impressions of Military Life in, ALBERT LÉON GUÉRARD, 364
Freud's Theories of the Unconscious, WILLIAM CHASE, 355

Galton, Francis, 309
GARRISON, FIELDING H., Ehrlich's Specific Therapeutics in Relation to Scientific Method, 209
Genesis of the Law of Gravity, JOHN C. SHEDD, 313
Genius and Physiognomy, CHARLES KASSEL, 158
Geographic Influences in the Evolution of Nations, WALTER S. TOWER, 164
Geography, Disciplinary Value of, W. M. DAVIS, 105, 223
Geometry, Euclid's, Is it merely a Theory? EDWARD MOFFAT WEYER, 554
Golf Ball, Dynamics of a, J. J. THOMSON, 184
Graduate College of Princeton University, 307
Gravity, Law of, Genesis of the, JOHN C. SHEDD, 313
Gray, Asa, The House of, 414
Greek Volunteers, The Services and the Rewards of the Old, FREDERIC EARLE WHITAKER, 477; Sculpture, What Masterpieces were known to the Men of the Renaissance? EDWARD S. HOLDEN, 610
GUÉRARD, ALBERT LÉON, Impressions of Military Life in France, 364

HARRIS, J. ARTHUR, The Measurement of Natural Selection, 521
Health, Instinct, JAMES FREDERICK ROGERS, 84; The Relation of the Manual Arts to, LEWIS M. TERMAN, 602
HOLDEN, EDWARD S., What Masterpieces of Greek Sculpture were known to the Men of the Renaissance? 610
HOPKINS, CYRIL G., The Story of the King and Queen, 251
HUMPHREYS, W. J., Weather Proverbs and their Justification, 428
Hyatt, Alpheus, ALFRED GOLDSBOROUGH MAYER, 129

Ibsen, Emerson and Nietzsche, the Individualists, LEWIS WORTHINGTON SMITH, 147
Indians, American, Language of the, A. L. KROEBER, 500
Individualists, The, Ibsen, Emerson and Nietzsche, LEWIS WORTHINGTON SMITH, 147
Industrial and Academic Efficiency, 100
Instinct, Health, JAMES FREDERICK ROGERS, 84

JORDAN, DAVID STARR, Manhood and War, 88

Kant and Evolution, ARTHUR O. LOVEJOY, 36
KASSEL, CHARLES, Physiognomy and Genius, 158
King and Queen, The Story of the, CYRIL G. HOPKINS, 251
KROEBER, A. L., The Language of the American Indians, 500

Laboratory, Cavendish, of Cambridge University, 517
Language, and Logic, CHARLES W. SUPER, 491; of the American Indians, A. L. KROEBER, 500
Living, Cost of, HENRY PRATT FAIRCHILD, 377
Logic and Language, CHARLES W. SUPER, 491
LOVEJOY, ARTHUR O., Kant and Evolution, 36
LUSK, GRAHAM, Alcohol—its Use and Abuse, 381

Manhood and War, DAVID STARR JORDAN, 88
Manual Arts in their Relation to Health, LEWIS M. TERMAN, 602
MARSHALL, F. R., The Relation of Agriculture to Biology, 539
MAYER, ALFRED GOLDSBOROUGH, Alpheus Hyatt, 129
Measurement of Natural Selection, J. ARTHUR HARRIS, 521
Medieval Universities, Science at the, JAMES J. WALSH, 445
Meteorology of the Future, CLEVELAND ABBE, 21
Military Lire in France, Impressions of, ALBERT LÉON GUÉRARD, 364
Minneapolis, Scientific Meetings at, 199
Minnesota, University of, 201
Motor Education for the Child, J. MADISON TAYLOR, 268
Mount Wilson Conference of the Solar Union, 101

Nations, Evolution of, Geographic Influences in the, WALTER S. TOWER, 164
Natural, Bridges, North American, The Formation of, HERDMAN F. CLELAND, 417; Selection, The Measurement of, J. ARTHUR HARRIS, 521
NEARING, SCOTT, Race Suicide *vs.* Over-population, 81
Nietzsche, Ibsen, Emerson, the Individualists, LEWIS WORTHINGTON SMITH, 147
North American Natural Bridges, The Formation of, HERDMAN F. CLELAND, 417

Over-population, Race Suicide *vs.*, SCOTT NEARING, 81

Palmer, Edward, WILLIAM EDWARD SAFFORD, 341

PATON, STEWART, University Reforms, 52
PATRICK, G. T. W., Search for the Soul in Contemporary Thought, 460
Philippines, Work of the "Albatross" in the, ALBERT I. BARROWS, 241
Philosophy of Professor Brooks, EDWARD GLEASON SPAULDING, 120
Physiognomy and Genius, CHARLES KASSEL, 158
Plant Diseases, Progress in the Control of, F. L. STEVENS, 469
Plants, Century, The Smallest of the, WILLIAM TRELEASE, 5
Population of the United States in 1910, 409
Princeton University, Graduate College of, 307
Professor, College, The Case of the, WARNER FITE, 273
Professors, About Dismissing, 305; Circulating, 516
Progress of Science, 100, 199, 305, 409, 516, 615
Proverbs, Weather, and their Justification, W. J. HUMPHREYS, 428
Psychologist, The Consulting, C. E. SEASHORE, 283

Queen and King, The Story of the, CYRIL G. HOPKINS, 251

Race Suicide vs. Over-population, SCOTT NEARING, 81
Reality and Truth, T. D. A. COCKERELL, 371
Reforms, University, STEWART PATON, 52
Research Work of the Carnegie Institution, 411
ROCKWOOD, ELBERT W., The Work of Chemistry in Conservation, 291
ROGERS, JAMES FREDERICK, The Health Instinct, 84

SAFFORD, WILLIAM EDWARD, Edward Palmer, 341
SANG, ALFRED, The Underlying Facts of Science, 564
Science, Progress of, 100, 199, 305, 409, 516, 615; at the Medieval Universities, JAMES J. WALSH, 445; The Underlying Facts of, ALFRED SANG, 564
Scientific, Items, 104, 204, 312, 414, 519, 620; Meetings at Minneapolis and Elsewhere, 199; Method, Ehrlich's Specific Therapeutics in Relation to, FIELDING H. GARRISON, 209; *versus* Personal Distribution of College Credits, WILLIAM T. FOSTER, 388; Societies, 615
Sculpture, Greek, What Masterpieces were known to the Men of the Renaissance? EDWARD S. HOLDEN, 610
SEASHORE, C. E., The Consulting Psychologist, 283
Selection, Natural, The Measurement of, J. ARTHUR HARRIS, 521
SHEDD, JOHN C., Genesis of the Law of Gravity, 313
SMITH, LEWIS WORTHINGTON, Ibsen, Emerson and Nietzsche, the Individualists, 147
Social Problem, JOHN J. STEVENSON, 258
Solar Union, Mount Wilson Conference of the, 101
Soul, Search for, in Contemporary Thought, G. T. W. PATRICK, 460
SPAULDING, EDWARD GLEASON, Professor Brooks's Philosophy, 120
STEVENS, F. L., Progress in Control of Plant Diseases, 469
STEVENSON, JOHN J., The Social Problem, 258
Suicide, Race, vs. Over-population, SCOTT NEARING, 81
SUPER, CHARLES W., Language and Logic, 491

TAYLOR, J. MADISON, Motor Education for the Child, 268
TERMAN, LEWIS M., The Relation of the Manual Arts to Health, 602
Therapeutics, Ehrlich's Specific, in Relation to Scientific Method, FIELDING H. GARRISON, 209
THOMSON, J. J., The Dynamics of a Golf Ball, 184
Thought, Contemporary, Search for the Soul in, G. T. W. PATRICK, 460
TOWER, WALTER S., Geographic Influences in the Evolution of Nations, 164
TRELEASE, WILLIAM, The Smallest of the Century Plants, 5.
Truth and Reality, T. D. A. COCKERELL, 371

Unconscious, Freud's Theories of the, WILLIAM CHASE, 355
Underlying Facts of Science, ALFRED SANG, 564
United States, Population of the, in 1910, 409
Universities, Medieval, Science at the, JAMES J. WALSH, 445
University Reforms, STEWART PATON, 52

Vienna Institution for Experimental Biology, CHARLES LINCOLN EDWARDS, 584
Volitional? Is the Diminishing Birth Rate, CHARLES FRANKLIN EMERICK, 71
Volunteers, Old Greek, The Services

and the Rewards of the, FREDERIC EARLE WHITAKER, 477
Wallace, Alfred Russel, 415
WALSH, JAMES J., Science at the Medieval Universities, 445
War and Manhood, DAVID STARR JORDAN, 88
Weather Proverbs and their Justification, W. J. HUMPHREYS, 428
WEYER, EDWARD MOFFAT, Is Euclid's Geometry merely a Theory? 554
WHITAKER, FREDERIC EARLE, The Services and the Rewards of the Old Greek Volunteers. 477

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VOL. LXXVIII, No. 6 JUNE, 1911

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CONTENTS

The Measurement of Natural Selection. Dr. J. ARTHUR HARRIS . . 521

The Relation of Biology to Agriculture. Professor F. R. MARSHALL . 539

Is Euclid's Geometry Merely a Theory. Dr. EDWARD MOFFAT WEYER 554

The Underlying Facts of Science. ALFRED SANG 564

The Vienna Institution for Experimental Biology. Prof. CHARLES LINCOLN EDWARDS 584

The Relation of the Manual Arts to Health. Professor LEWIS M. TERMAN 602

What Masterpieces of Greek Sculpture were known to the Men of the Renaissance? Dr. EDWARD S. HOLDEN 610

The Progress of Science:

Meetings of Scientific Societies; The Centenary of the Birth of John William Draper; Henry Nathaniel Bowditch; Scientific Items 615

Index to Volume LXXVIII 621

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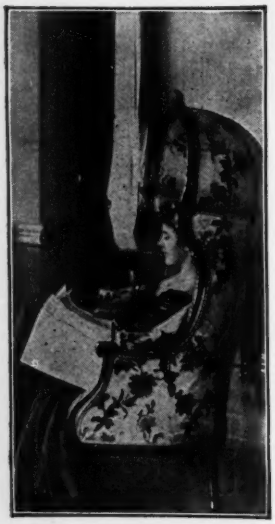

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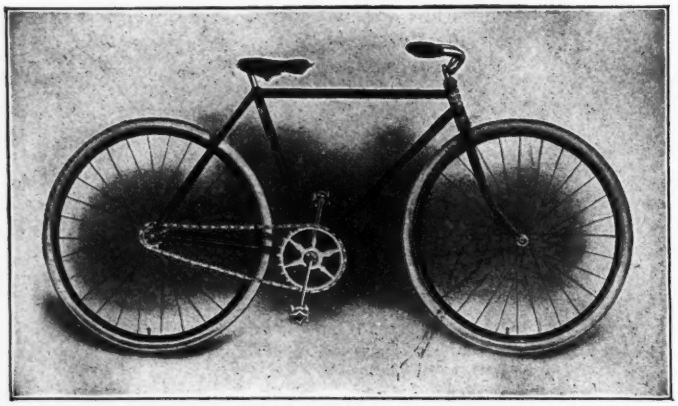

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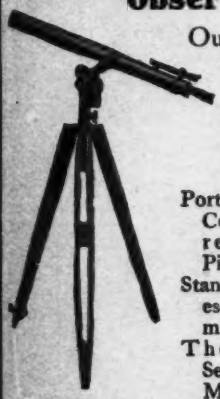

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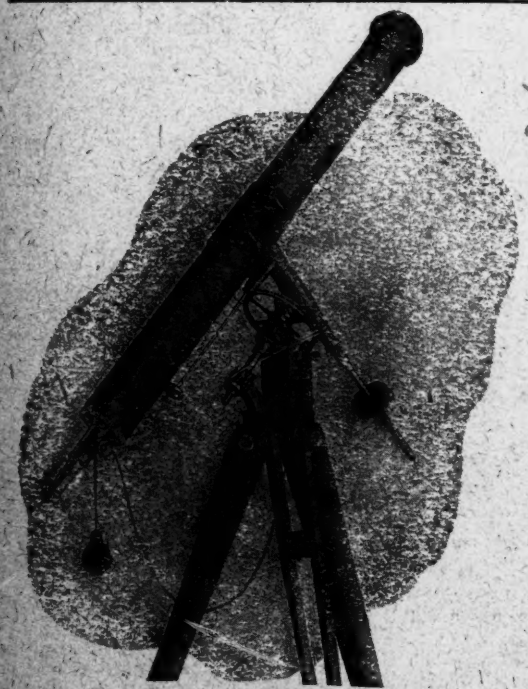

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